

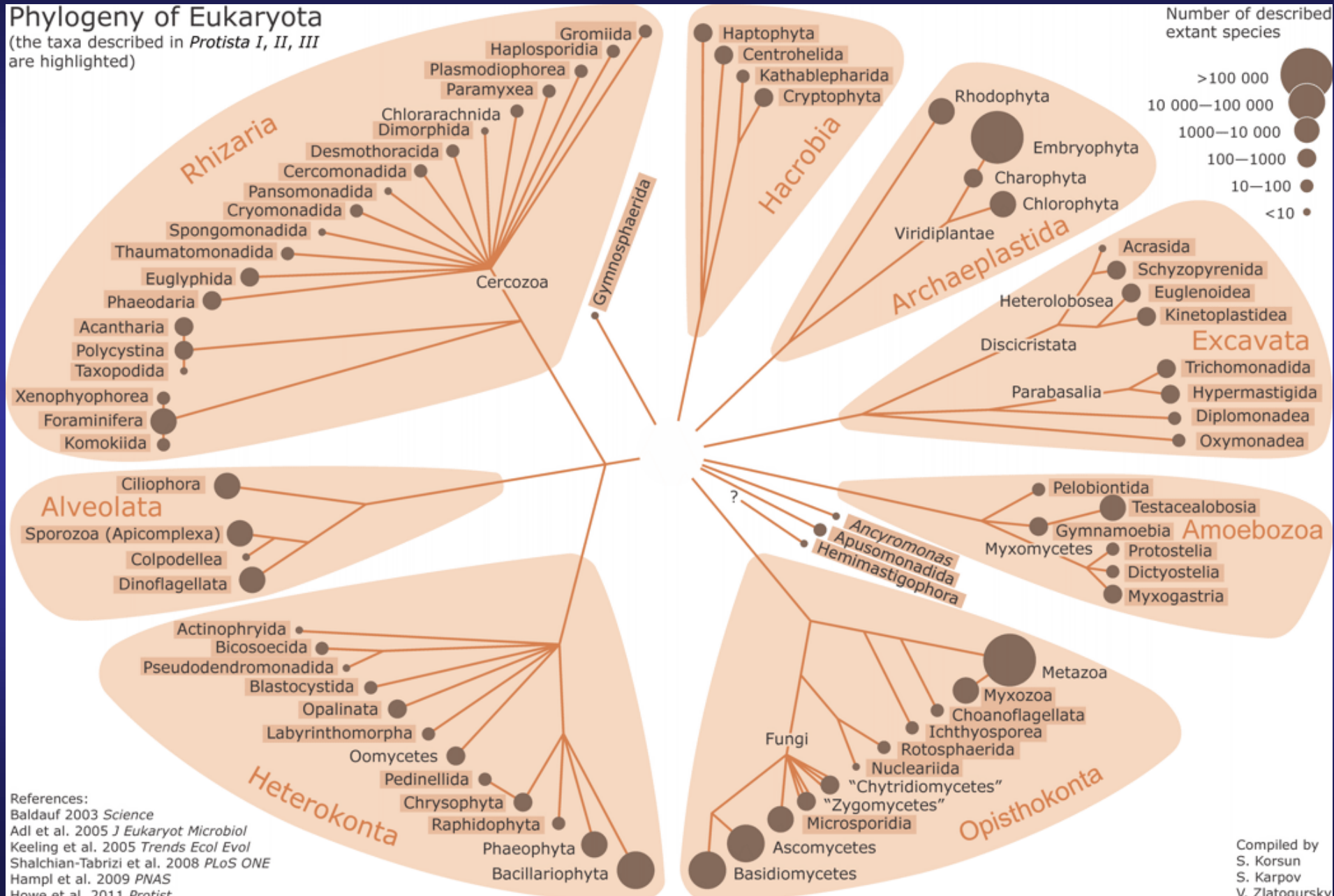
Паразитизм среди протистов:

паразитизм и смежные явления,
распространение, примеры

Филогенетические связи эукариот

Phylogeny of Eukaryota

(the taxa described in *Protista I, II, III* are highlighted)



References:
 Baldauf 2003 *Science*
 Adl et al. 2005 *J Eukaryot Microbiol*
 Keeling et al. 2005 *Trends Ecol Evol*
 Shalchian-Tabrizi et al. 2008 *PLoS ONE*
 Hampl et al. 2009 *PNAS*
 Howe et al. 2011 *Protist*

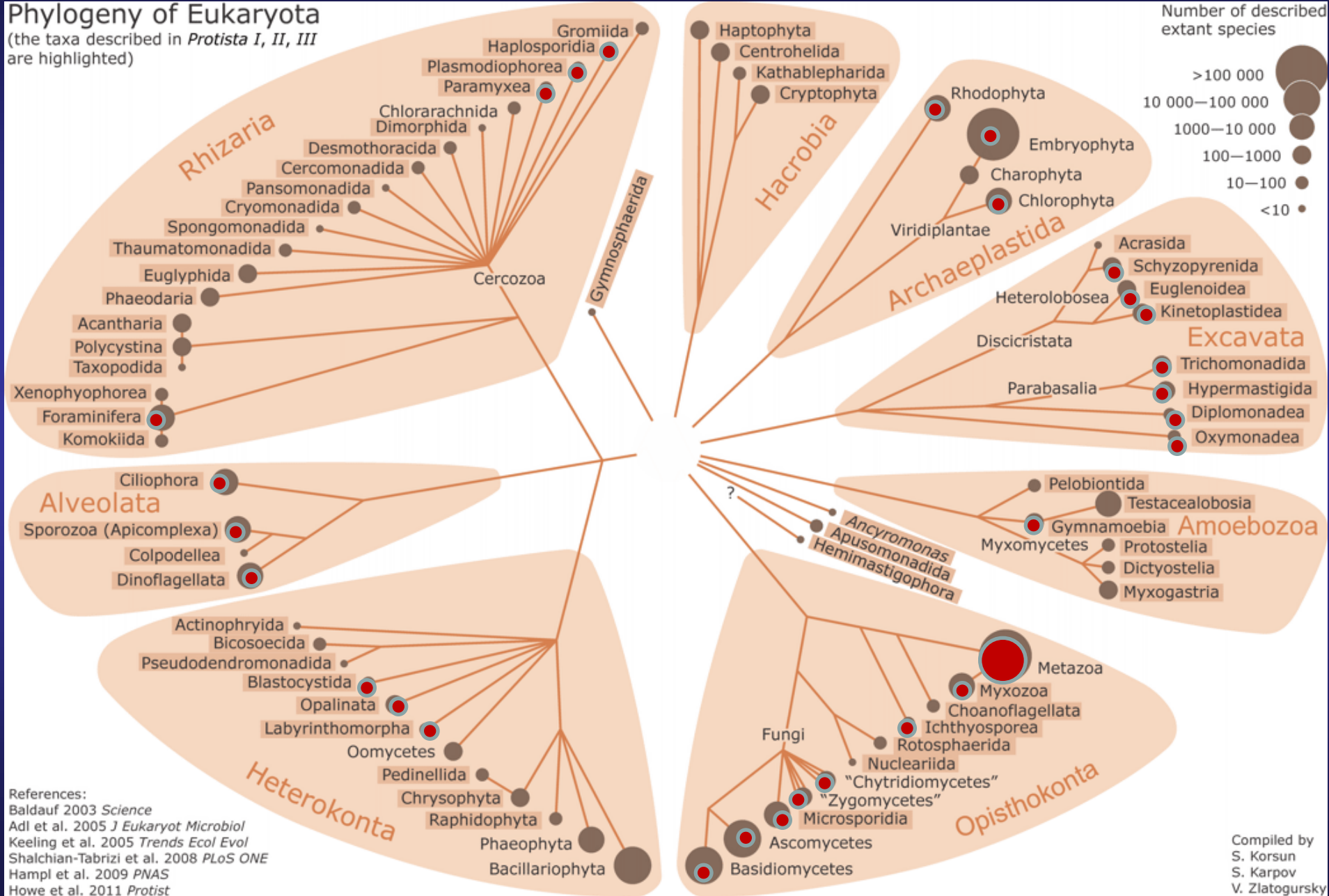
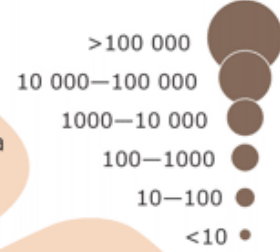
Compiled by
 S. Korsun
 S. Karpov
 V. Zlatogursky

Паразитизм как образ жизни среди эукариот

Phylogeny of Eukaryota

(the taxa described in *Protista I, II, III* are highlighted)

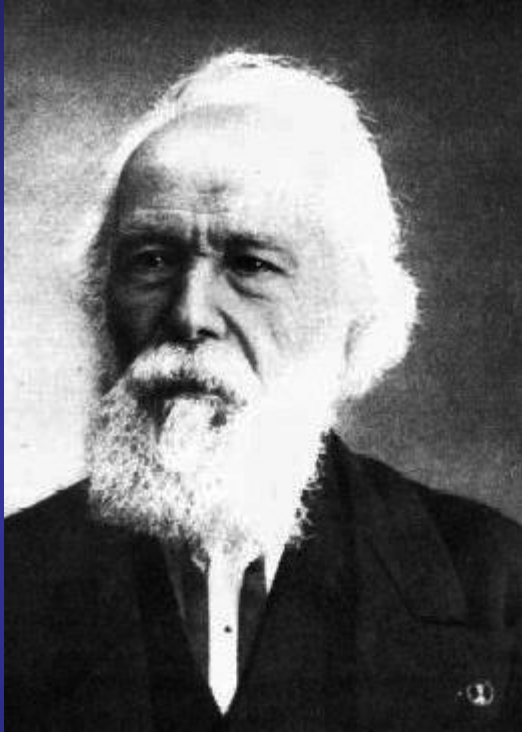
Number of described extant species



References:
Baldauf 2003 *Science*
Adl et al. 2005 *J Eukaryot Microbiol*
Keeling et al. 2005 *Trends Ecol Evol*
Shalchian-Tabrizi et al. 2008 *PLoS ONE*
Hampel et al. 2009 *PNAS*
Howe et al. 2011 *Protist*

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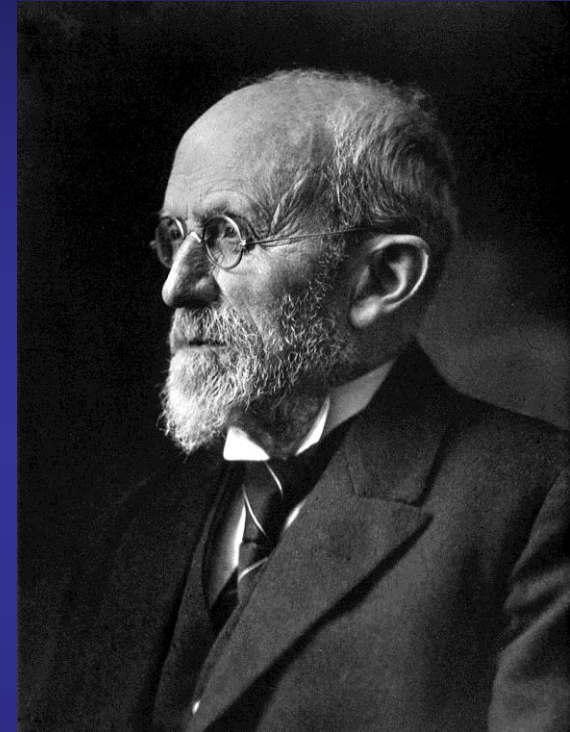
Symbiosis



Pierre-Joseph van Beneden
(19 December 1809 – 8 January 1894) was a Belgian [zoologist](#) and [paleontologist](#).



Heinrich Anton de Bary
(26 January 1831 – 19 January 1888) was a [German surgeon](#), [botanist](#), [microbiologist](#), and [mycologist](#) ([fungal systematics](#) and [physiology](#)).



Richard Wilhelm Karl Theodor Ritter von Hertwig
(23 September 1850 – 3 October 1937) was a [German zoologist](#)

Evolution: Causality and the Origin of Parasitism (Janouškovec and Keeling, 2016)

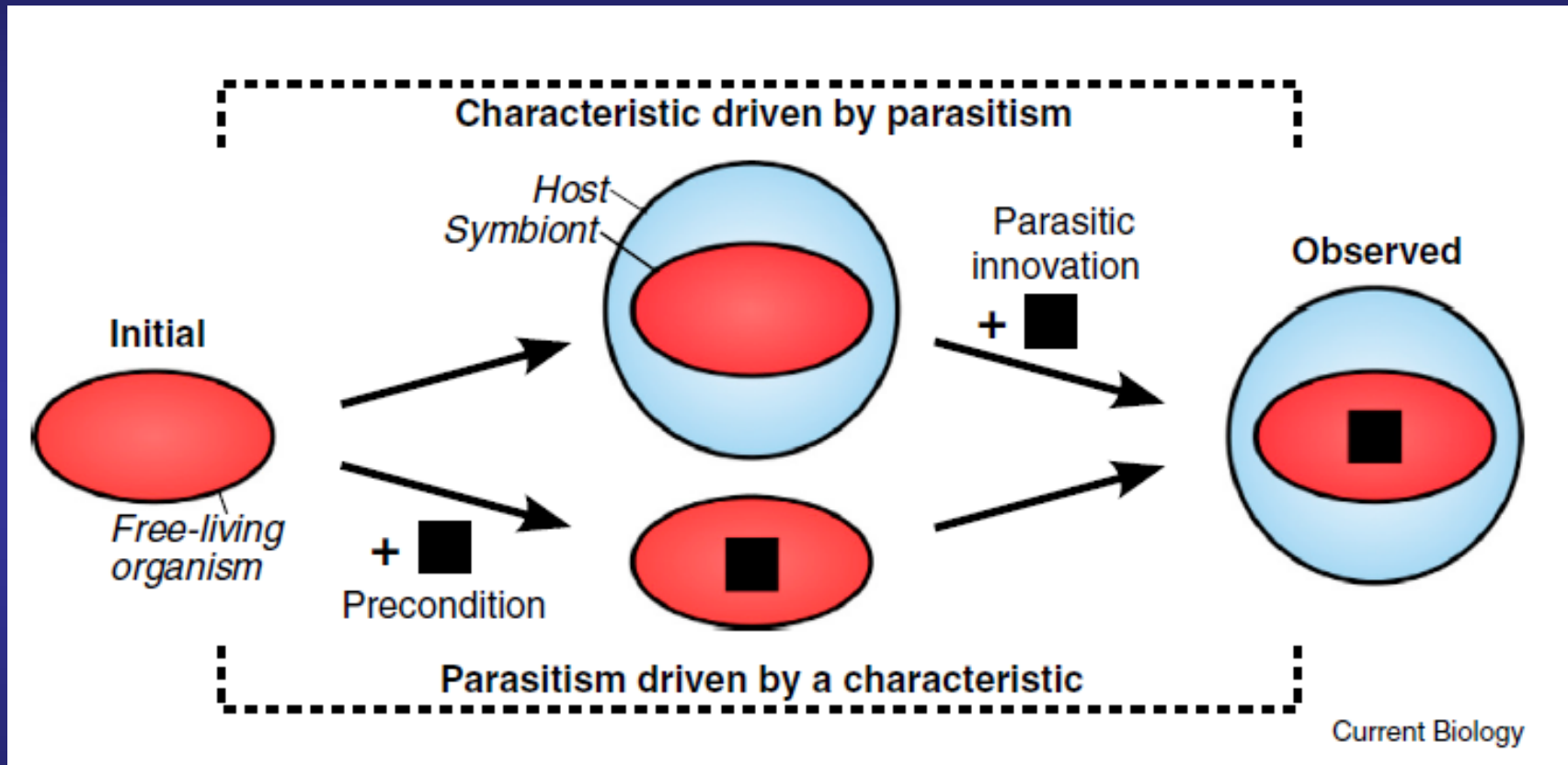
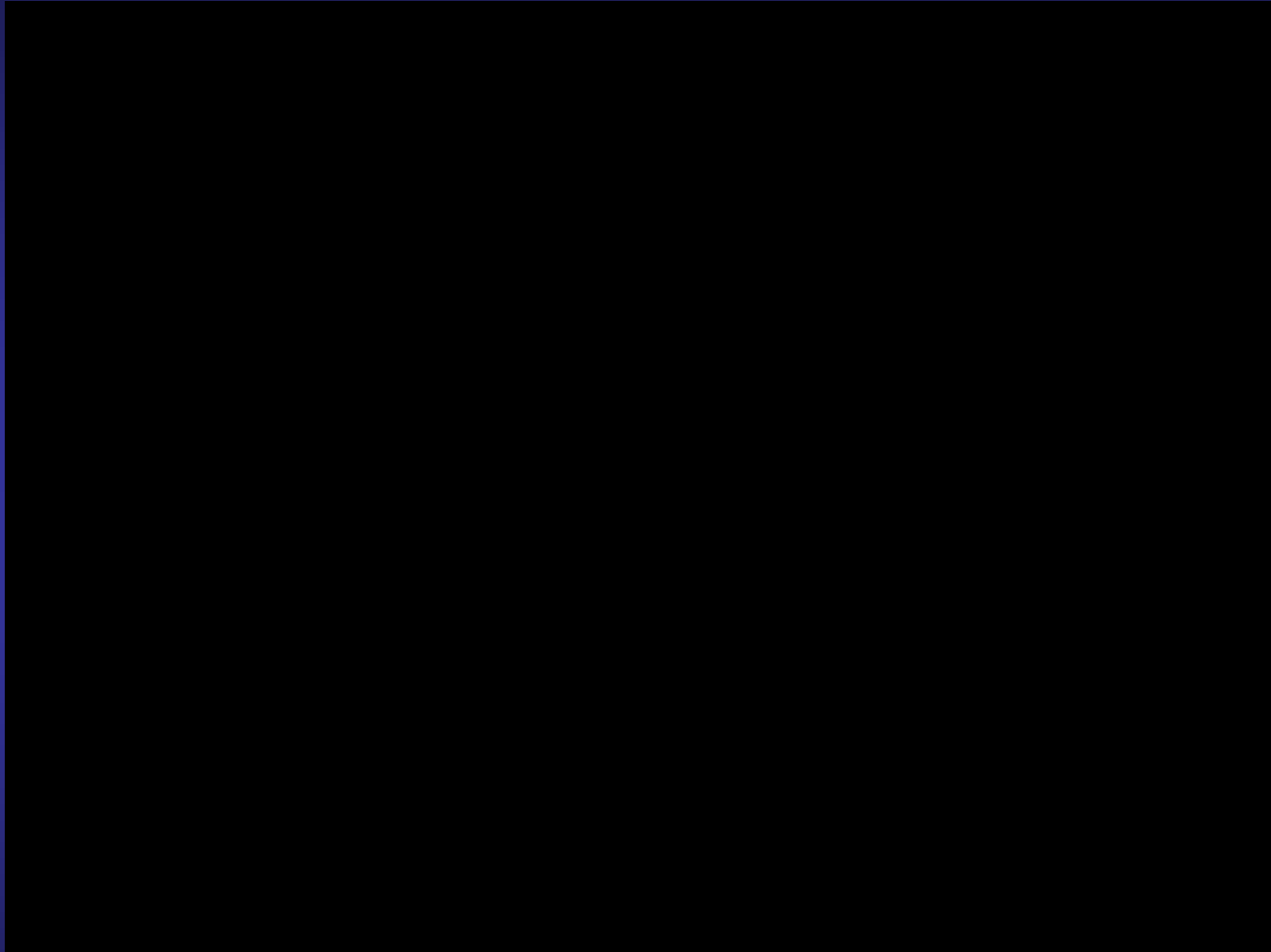


Figure. Models for the transition of free-living organisms to parasites, and their character states.

Two alternative ways to interpret the characteristics of parasites and how they relate to the origin of parasitism. On the top, a characteristic evolves as an adaptation to the existence of a parasitic interaction. On the bottom, the characteristic evolves in a free-living organism, but its existence makes the transition to parasitic life more likely, so it preconditions the lineage to a parasitic transition.

Foraminifera

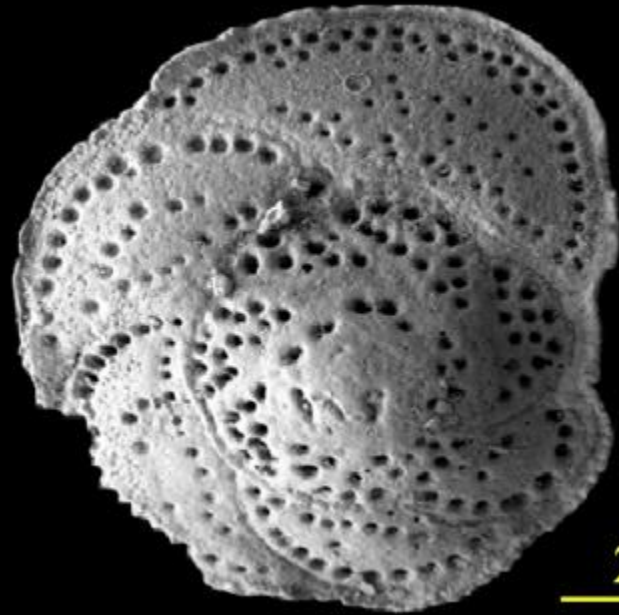


<https://www.youtube.com/watch?v=-jpJhDHSWow>

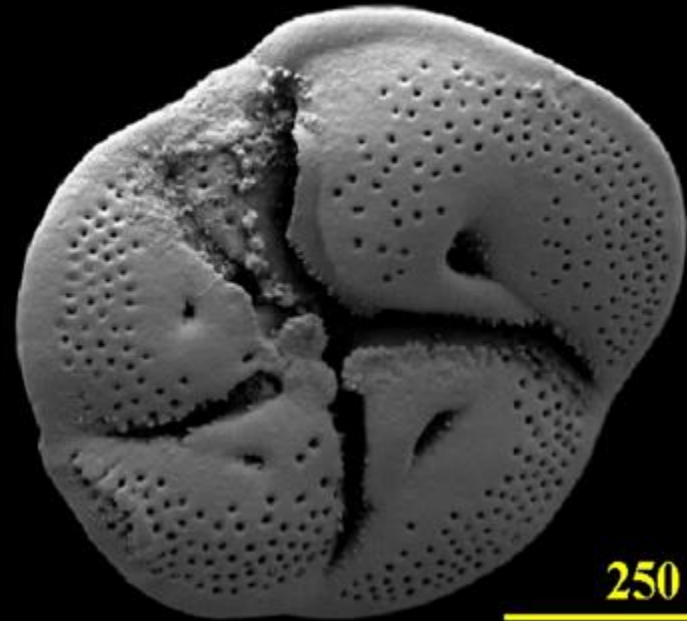
Foraminifera as epibionts, predators, commensals and parasites



Fissurina marginata как эктопаразит на фораминифере *Discorbis* sp. (Le Calvez, 1947).
Никогда не культивировалась без хозяина.



200 um



250 um

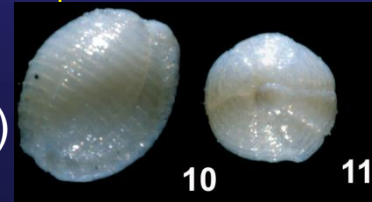


Rosalina carnivora была описана как комменсал, который высверливает ямы на поверхности раковины *Lima (=Acesta) angolensis*. Автор не называла фораминиферу истинным паразитом (Todd, 1965)



Floresina amphiphaga preying upon *Amphistegina*.

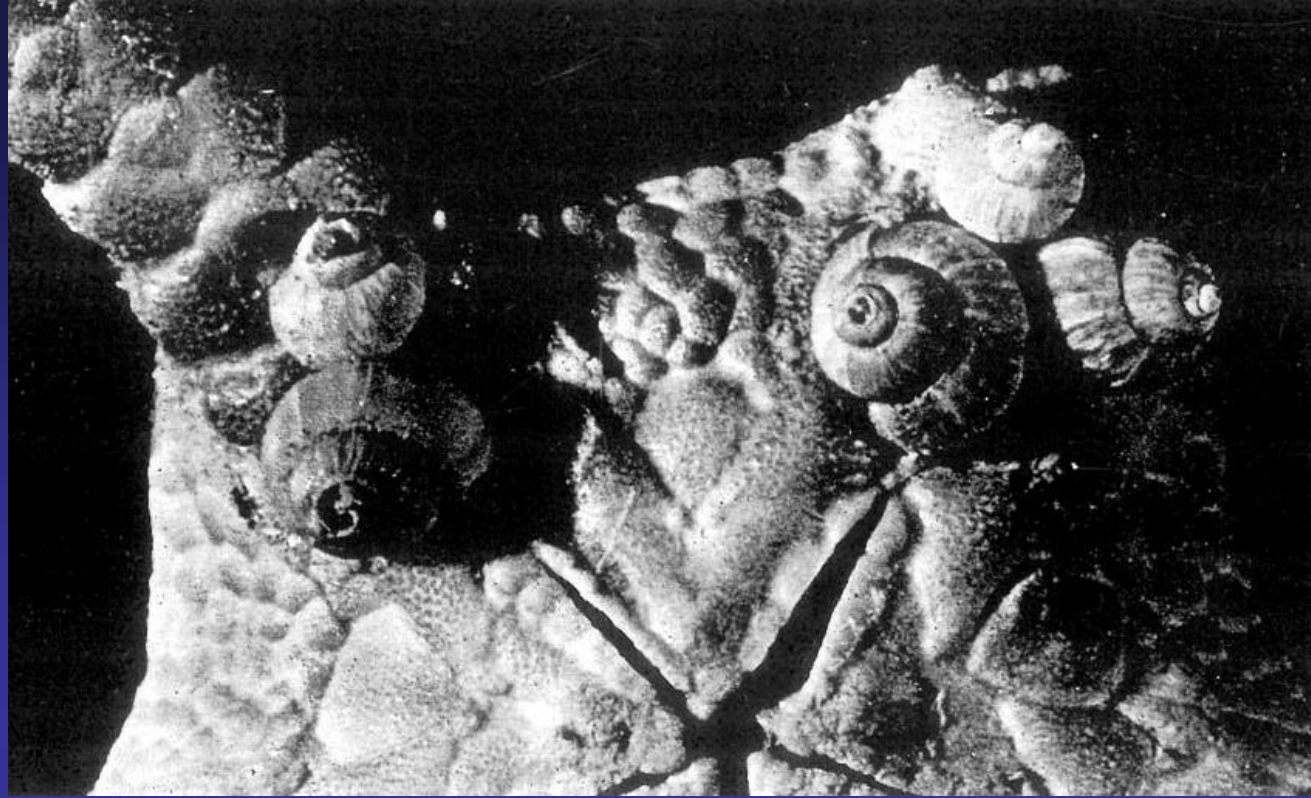
Planorbulinopsis parasita является паразитом других фораминифер (*Alveolina* sp.) (Banner, 1971).





Hanzawaia strattoni в норме живет на *Notocorbula operculata*, но не считается паразитом (Bock, Moore, 1968).

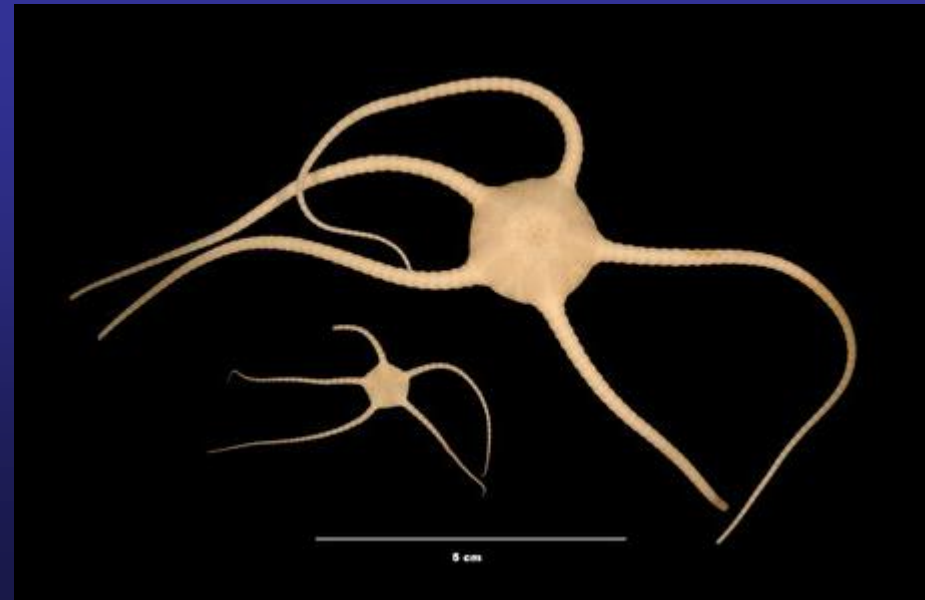




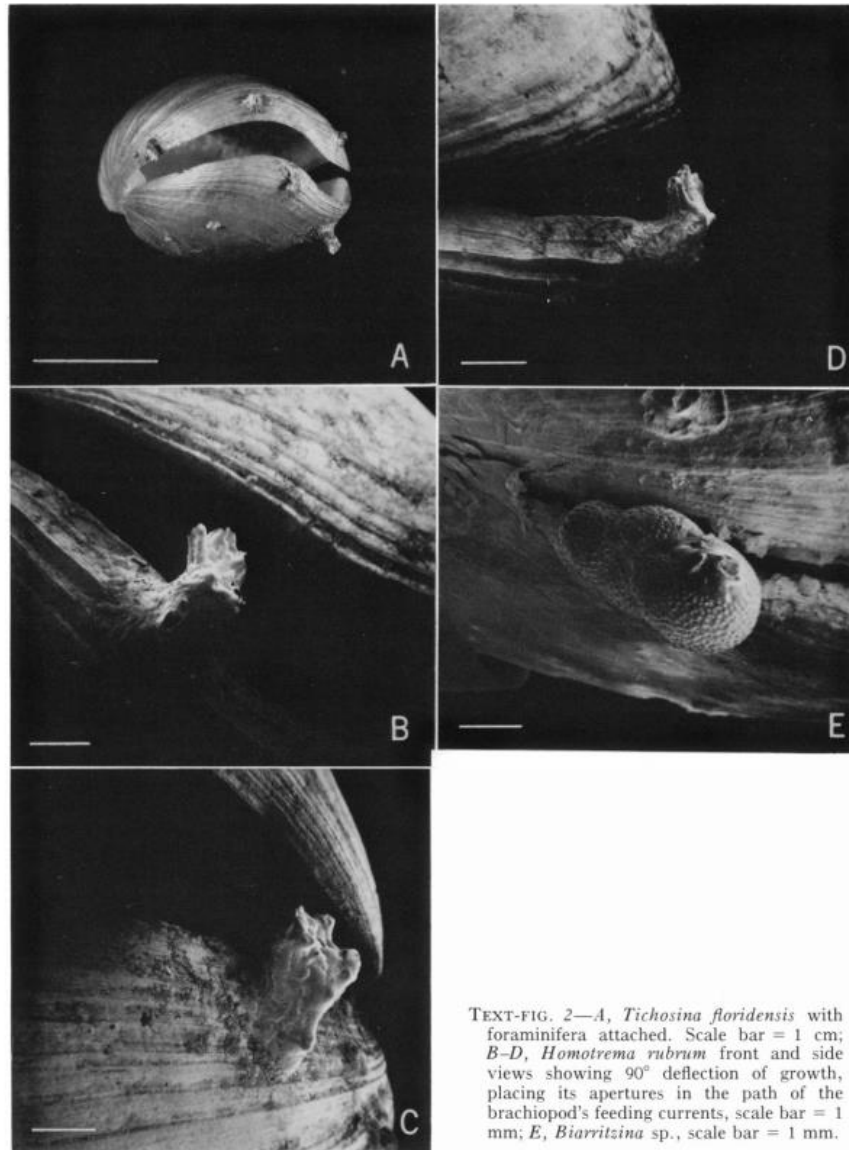
Гиперпаразитические
фораминиферы
поражают раковину
гастроподы *Ophiolamia
armigeri*, которая
является паразитом
змеехвостки
Ophiomusium armigerum
(Waren, Carney, 1981)



Stilapex montrouzieri (Eulimidae) attached to a large brittle
star (*Macrophiothirx sp.*), Moorea, French Polynesia



Foraminifera as epibionts on brachiopods

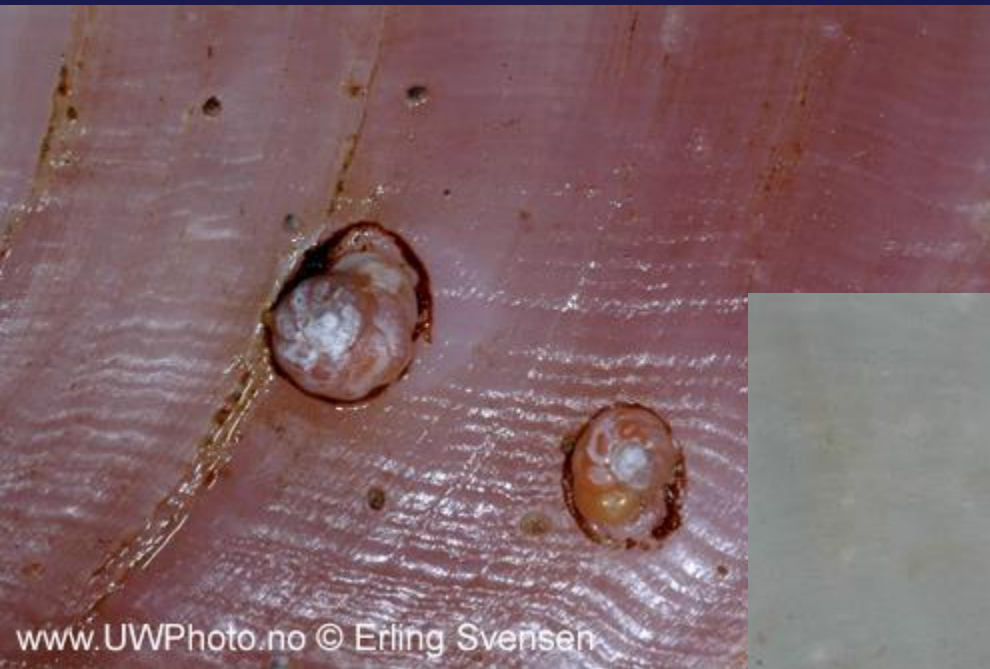


TEXT-FIG. 2—A, *Tichosina floridensis* with foraminifera attached. Scale bar = 1 cm; B–D, *Homotrema rubrum* front and side views showing 90° deflection of growth, placing its apertures in the path of the brachiopod's feeding currents, scale bar = 1 mm; E, *Biarritzina* sp., scale bar = 1 mm.

Несколько видов фораминифер живет на брахиоподе *Tichosina floridensis*. Токи воды, создаваемые этой зверюшкой, используются для питания самой фораминиферой

(Zumwalt, DeLaca, 1980)

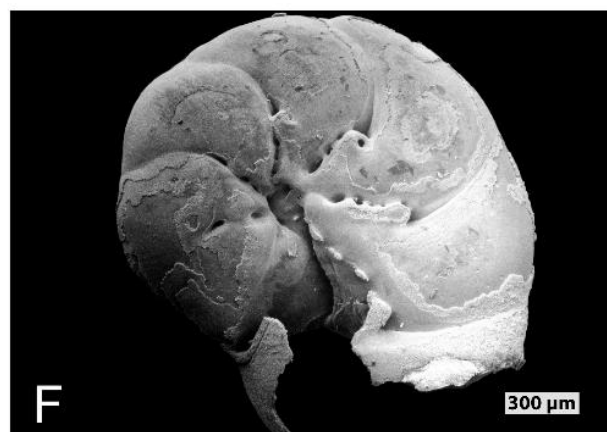
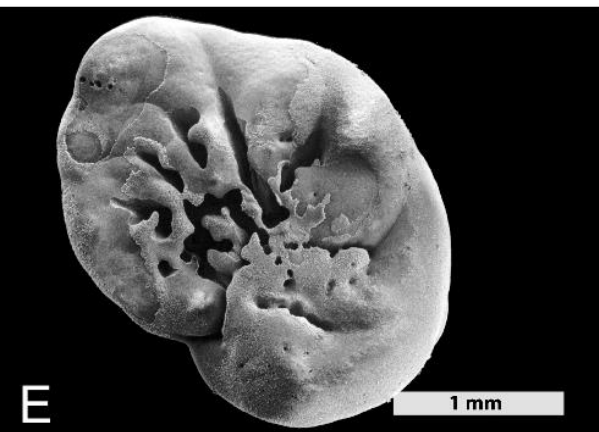
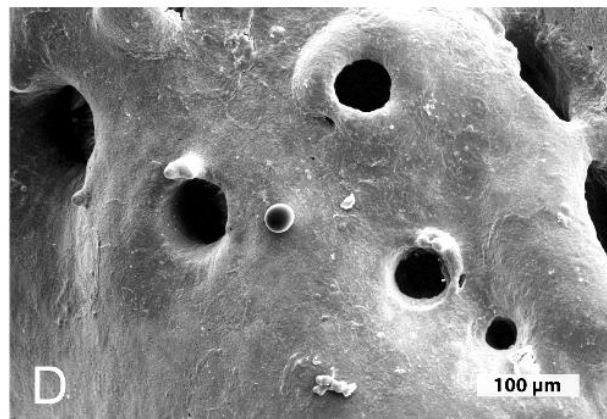
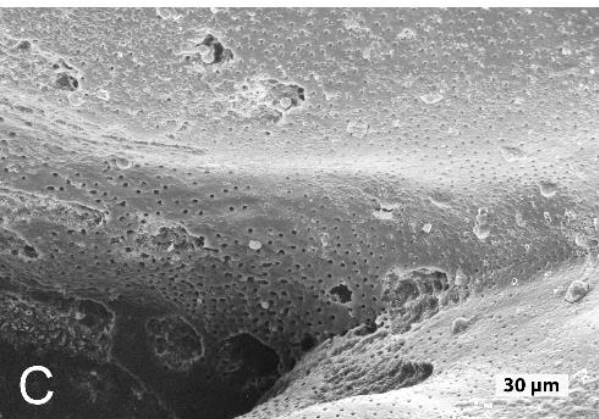
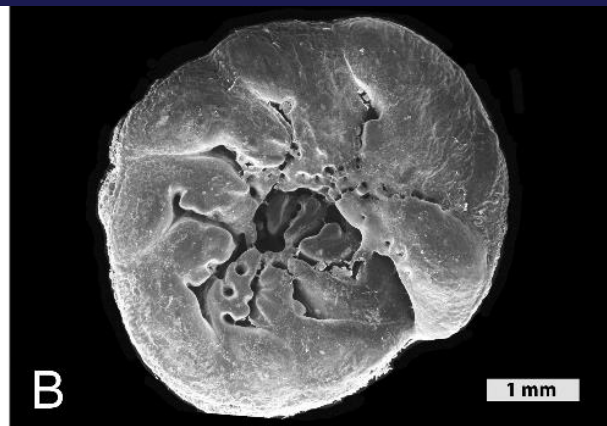
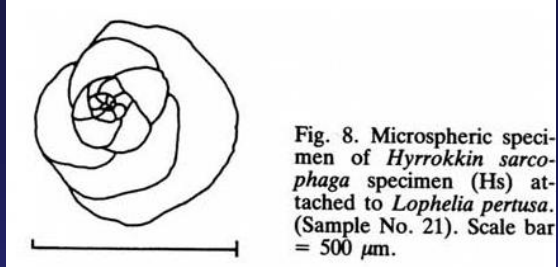
Hyrrokkin sarcophaga as a parasite



Hyrrokkin sarcophagi была известная под разными именами, позже все были сведены в один вид, паразиты моллюсков и губок (Cedhagen, 1994).



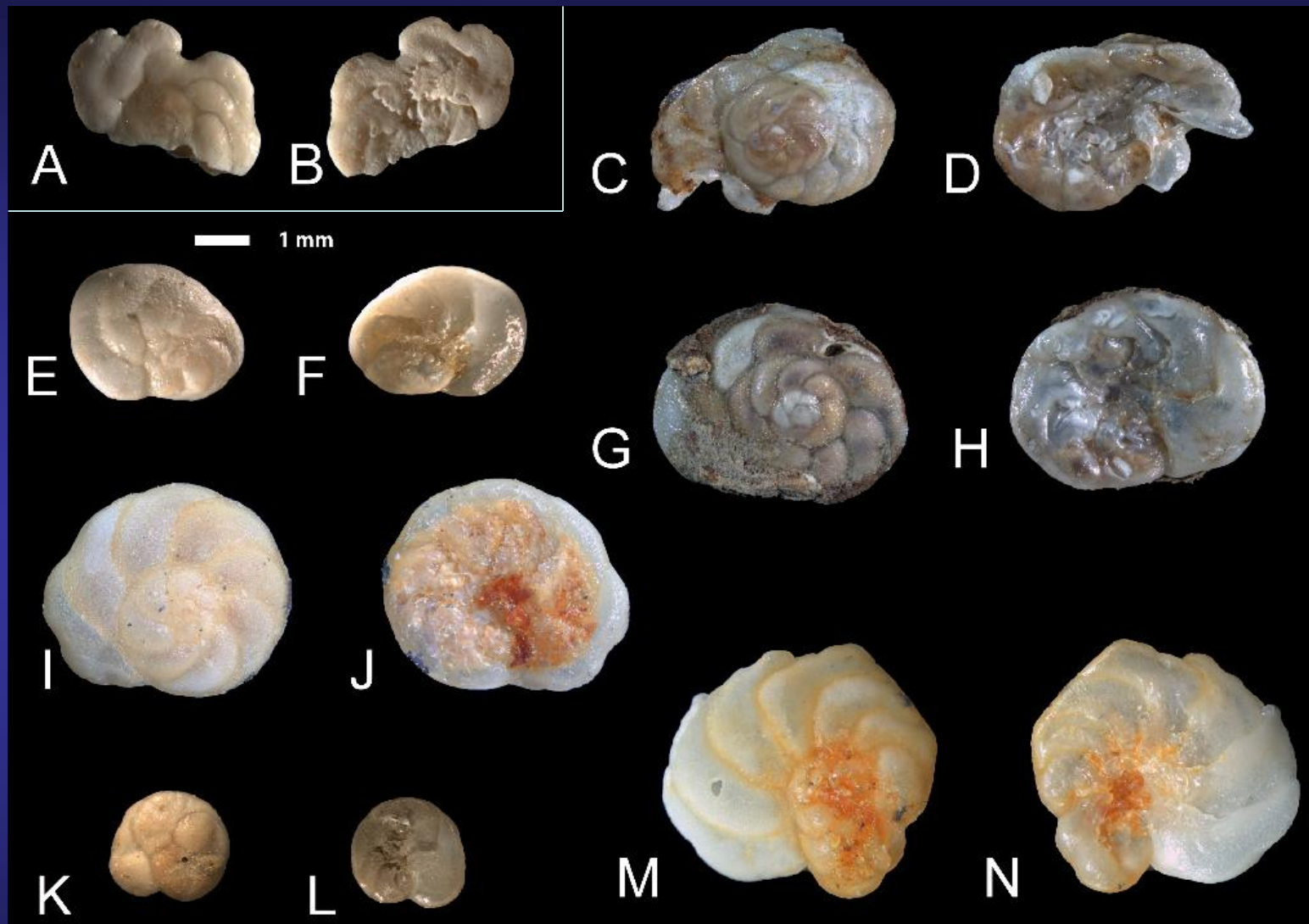
Hyrrokkin sarcophaga as a parasite



Variations of *Hyrrokkin sarcophaga* test morphology (A: microscopic image, B-H: SEM). **A** Umbilical side of *H. sarcophaga* on *Lophelia pertusa* (Pos228-200-3). **B** SEM image of **A** accents the distribution of apertures. **C** Close-up of **B** showing numerous pores. **D** Close-up of the larger test apertures, where the protoplasm exits to form the 'whip'-shaped canals in the substrate. **E** Test from *L. pertusa*, irregular substrate morphologies influence the shape of the foraminifer (Pos228-200-3). **F** Test from geodiid host (POS228-201).

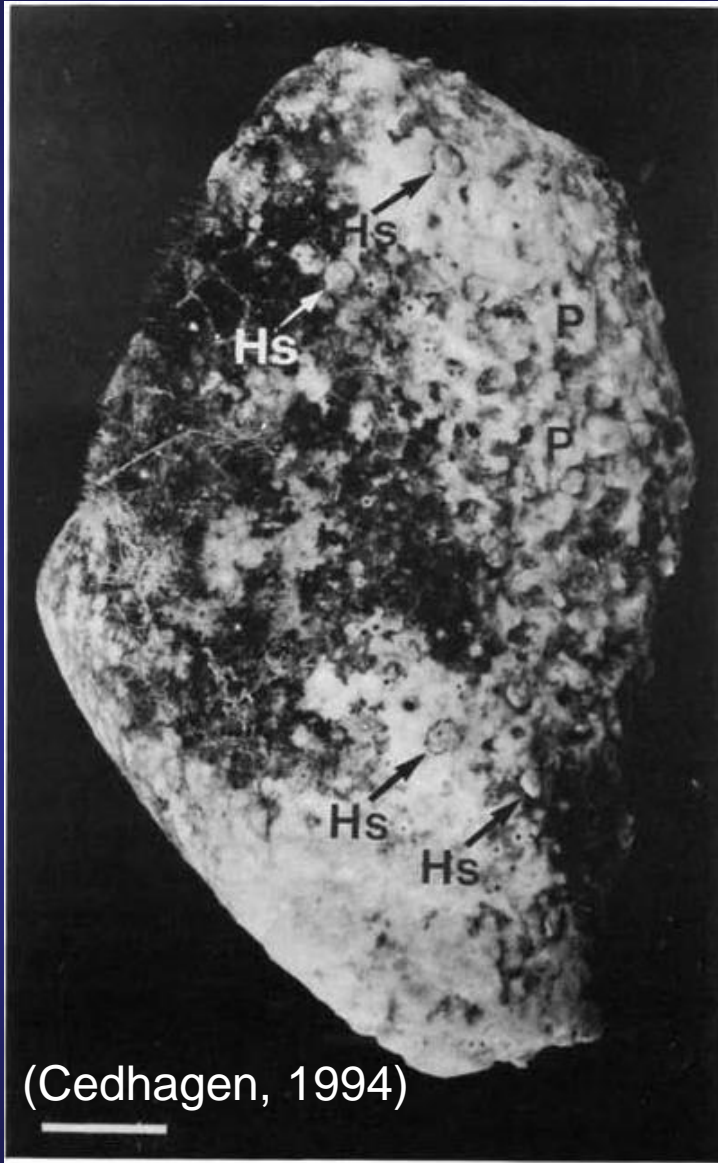
(Beuck et al., 2008)

Hyrrokkin carnivora and *H. sarcophaga* as parasites



Recent *Hyrrokkin* spp. from various hosts show a high morphological variability, depending on their substrate topography (A-B: *Hyrrokkin carnivora*, Mauritania; C-N: *Hyrrokkin sarcophaga*, mid-Norway; upper side and umbilical side pictured adjacent; the same scale bar applies to all specimens). A-B *H. carnivora* (specimen from Fig. 4I), host *Acesta excavata*. C-D Host *Lophelia pertusa* (Pos228-228). E-F Host *Caryophyllia sarsiae* (M61-3-603-1). G-H like C-D, note the brown organic residuals skirting the test. I-J Host *A. excavata* (VH95-168). K-L Host geodiid sponge (POS228-201). M-N like I-J

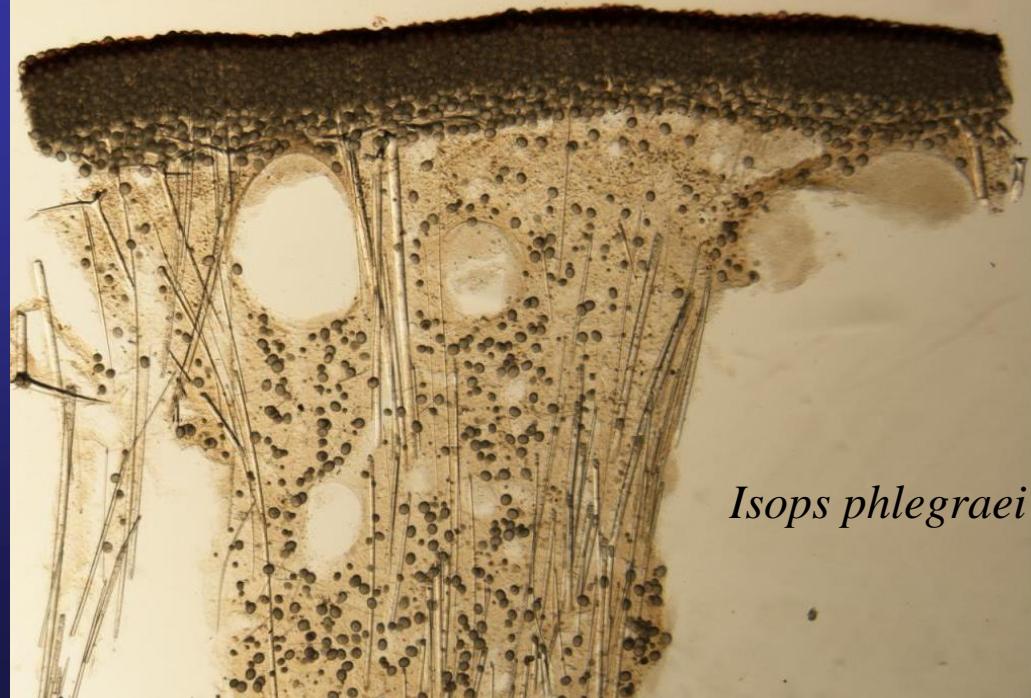
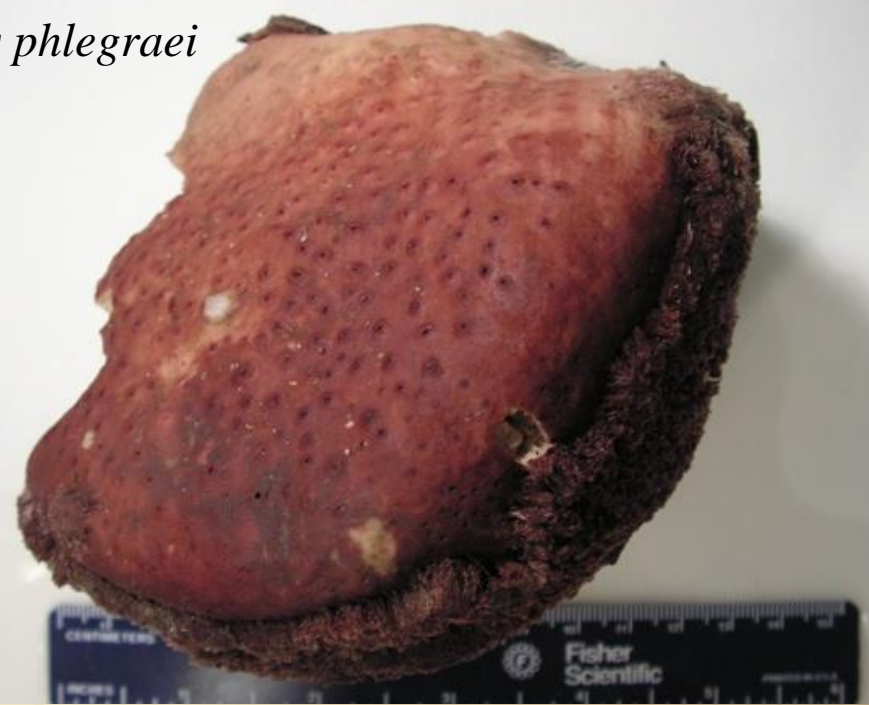
Hyrrokkin sarcophaga as a
parasite on sponges



(Cedhagen, 1994)

Fig. 10. *Hyrrokkin sarcophaga* (Hs) sitting on a fragment of a large *Isops phlegraei* specimen. p = pits (see Sample No. 4).

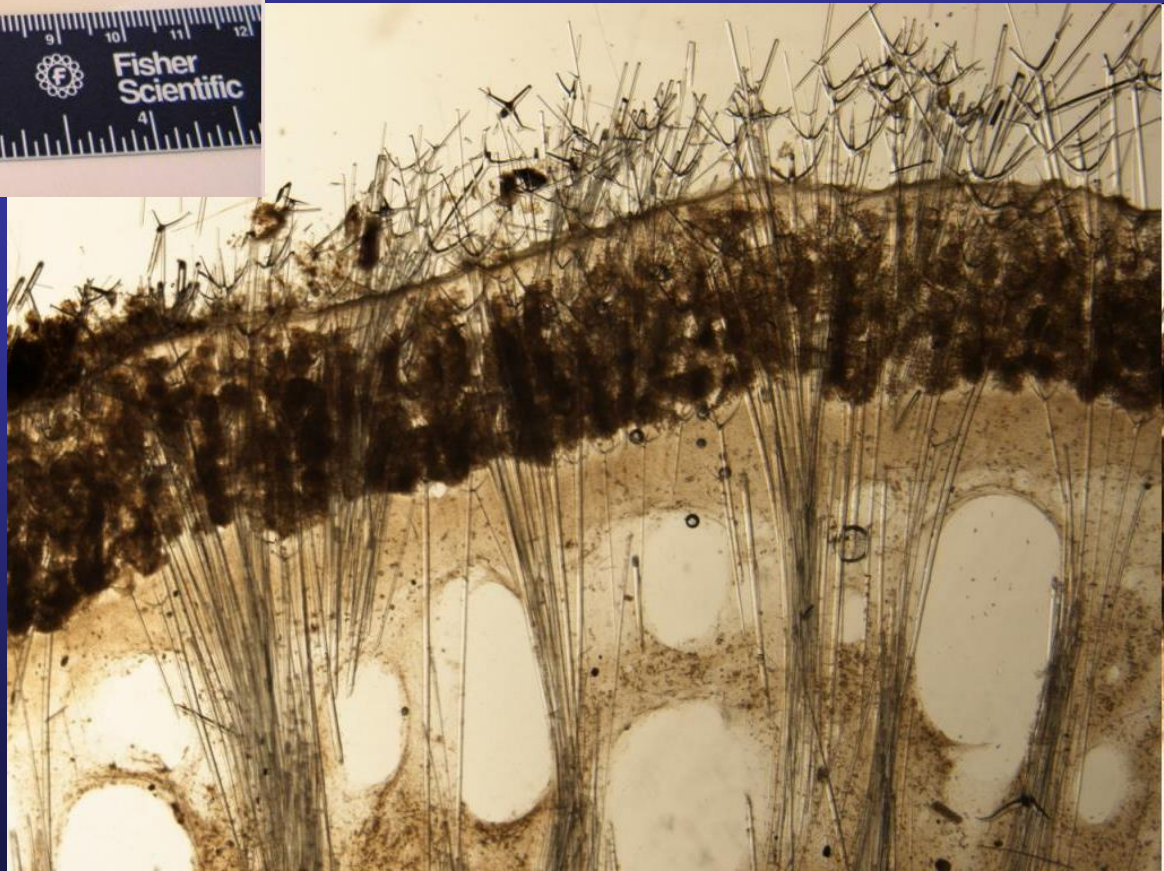
Isops phlegraei



Isops phlegraei



Stelletta normani





Lophelia pertusa

На коралле *Lophelia pertusa* встречаются представители нескольких видов беспозвоночных: двустворчатные моллюски *Acesta excavata*, *Delectopecten vitreus*, морские желуди *Verruca stroemia* и фораминифера *Hyrrokkin sarcophaga*

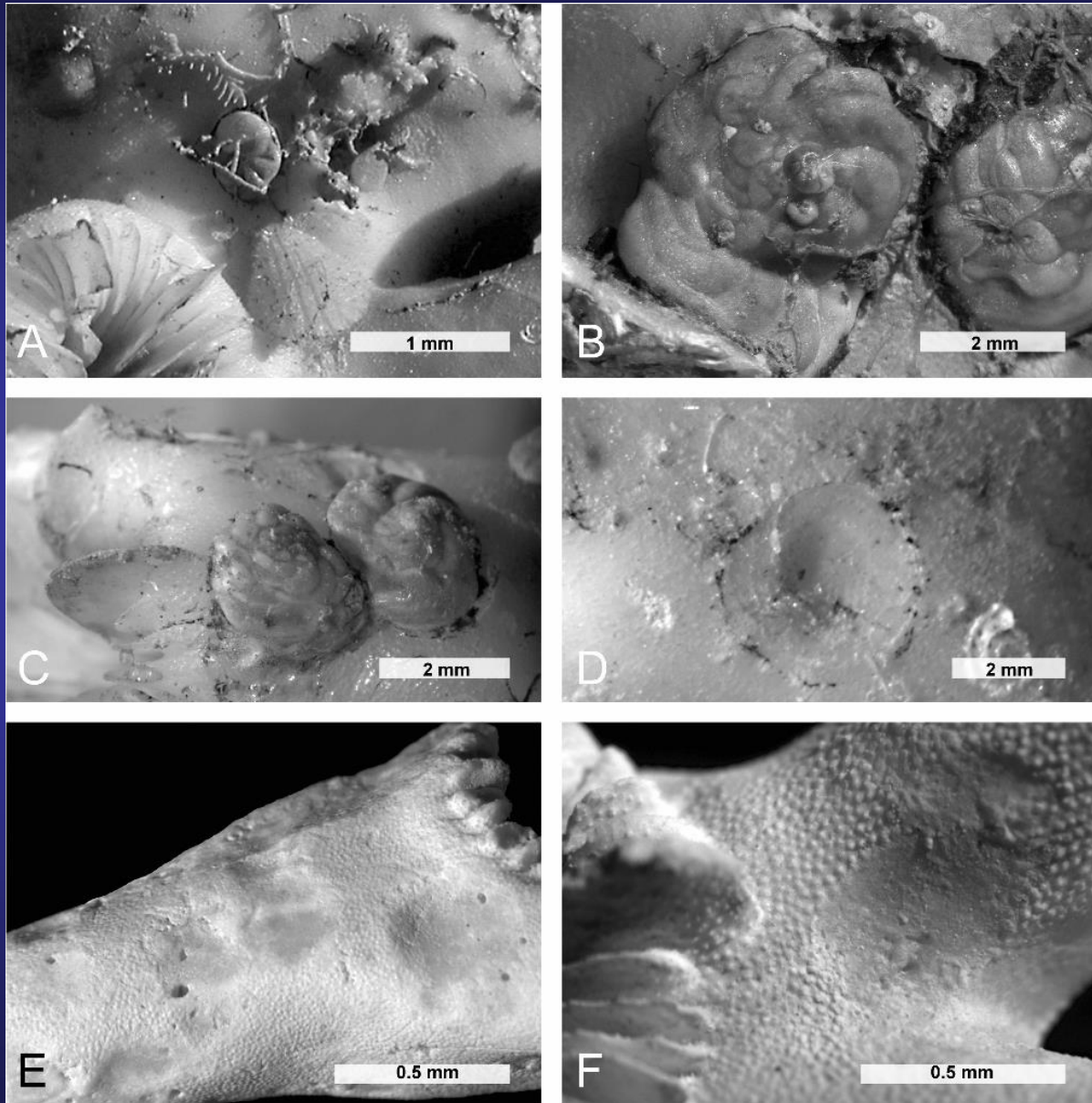


Acesta excavata
Norway, Nordland, Lofoten Islands
NMR 35834. Actual size 136 mm



Delectopecten vitreus
North Sea, English Klondike
NMR 38951. Common size 15 mm

Hyrrokkin sarcophaga as a parasite on corals



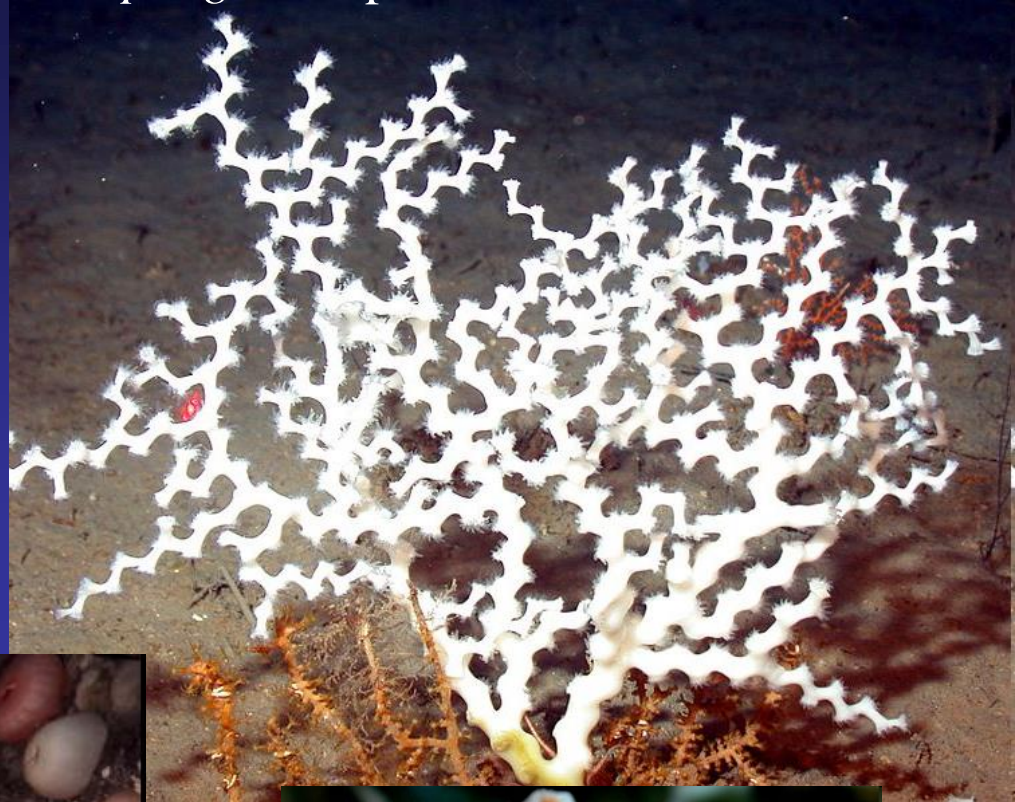
Microscopic images of Recent (A-D) and fossil (E-F) *Lophelia pertusa* samples. **A** *Hyrrokkin sarcophaga* colonising dead framework in association with the brachiopod *Terebratulina retusa*, epizoic bryozoans and serpulids (Pos228-200-3). **B** Two *Hyrrokkin sarcophaga* tests colonised by bryozoans and other foraminifers; note the partial embedding of the left individual (top) by the coral (JH5-99-4); image with courtesy of K. Kaszemeik. **C** *Hyrrokkin* individuals preferentially colonise upper calyx portions (Pos228-200-3). **D** *Hyrrokkin* groove on recently dead skeleton (LI94-163). **E** Fossil, Last Glacial *L. pertusa* with numerous potential *Hyrrokkin* traces (CS96-64). **F** Same coral as in E with potential *Hyrrokkin* groove in vicinity to the polyp; note the well preserved coral surface

(Beuck et al., 2008)

Sea Corn
Primnoa resedaeformis

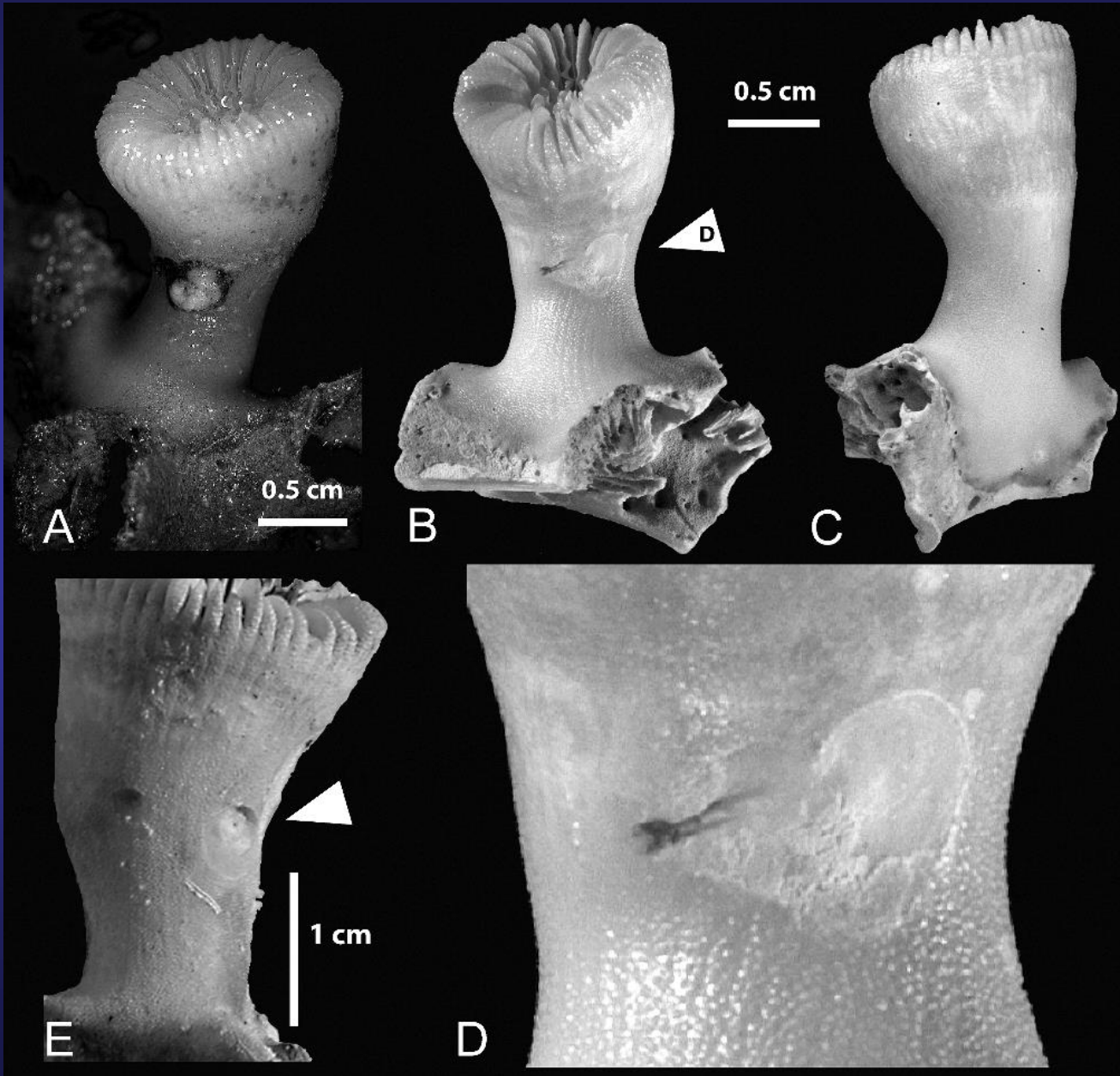


Hyrrokkin sarcophaga as a parasite on corals



Zigzag coral
Madrepora oculata

Hyrrokkin sarcophaga as a parasite on corals



Overview images of *Caryophyllia sarsiae* samples from the Porcupine Seabight; samples M61-3-603-1 (A-D) and M61-3-603-2. (E). **A** Live *Caryophyllia sarsiae* on dead *Lophelia pertusa* framework with live *Hyrrokkin sarcophaga* at the polyp's basal edge; note the brownish organic residue skirting the foraminiferan test. **B** Sample cleaned from organic remains and the *Hyrrokkin* test, now exposing *Kardopomorphos polydioryx* igen. n., isp. n. **C** The 'backside' of the corallite is free from foraminiferal traces. **D** Close-up of the shallow pit showing that the protoplasm seems to form a shallow depression (left) apically to the latest chamber. **E** Sample M61-3-603-2. Abandoned attachment scar of *Hyrrokkin sarcophaga* on a dead *Caryophyllia sarsiae*, exposing a central canal (white arrow)

(Beuck et al., 2008)

Hyrrokkin sarcophaga as a parasite on bivalves

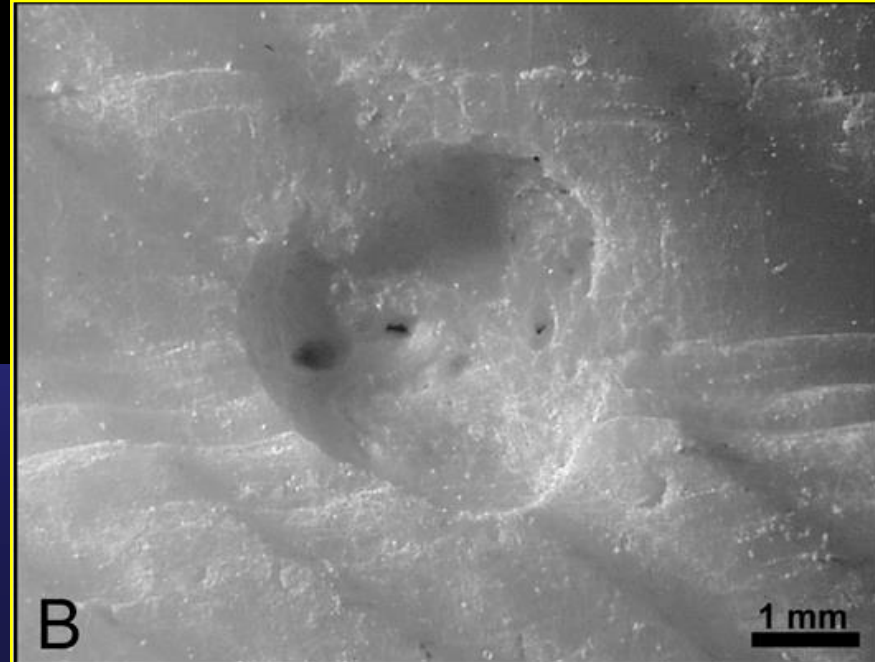


Acesta excavata
Norway, Nordland, Lofoten Islands
NMR 35834. Actual size 136 mm



A

1 mm



B

1 mm

Hyrrokkin sarcophaga as a parasite on bivalves



Acesta excavata
Norway, Nordland, Lofoten Islands
NMR 35834. Actual size 136 mm

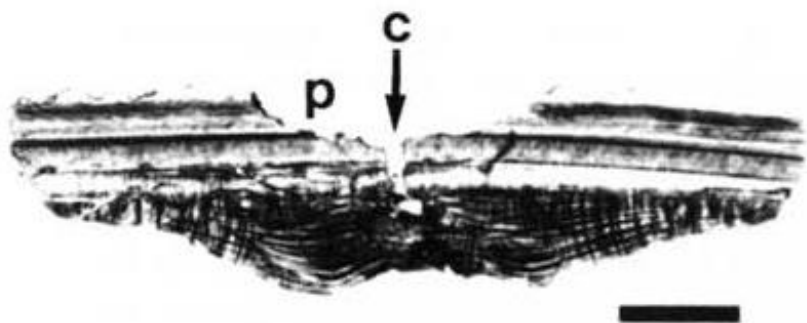


Fig. 6. Thin section of a pit (p) and a canal (c) made by *Hyrrokkin sarcophaga* sp. n. in the shell of *Lima (Acesta) excavata*. (Sample No. 32, SMNH No. 4587). Scale bar = 1 mm.

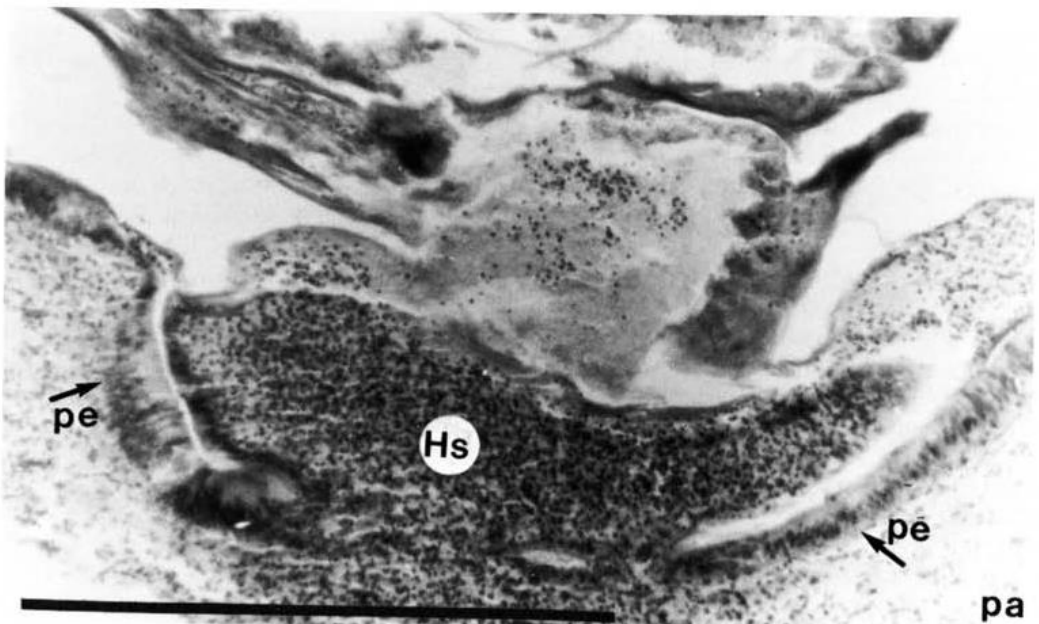
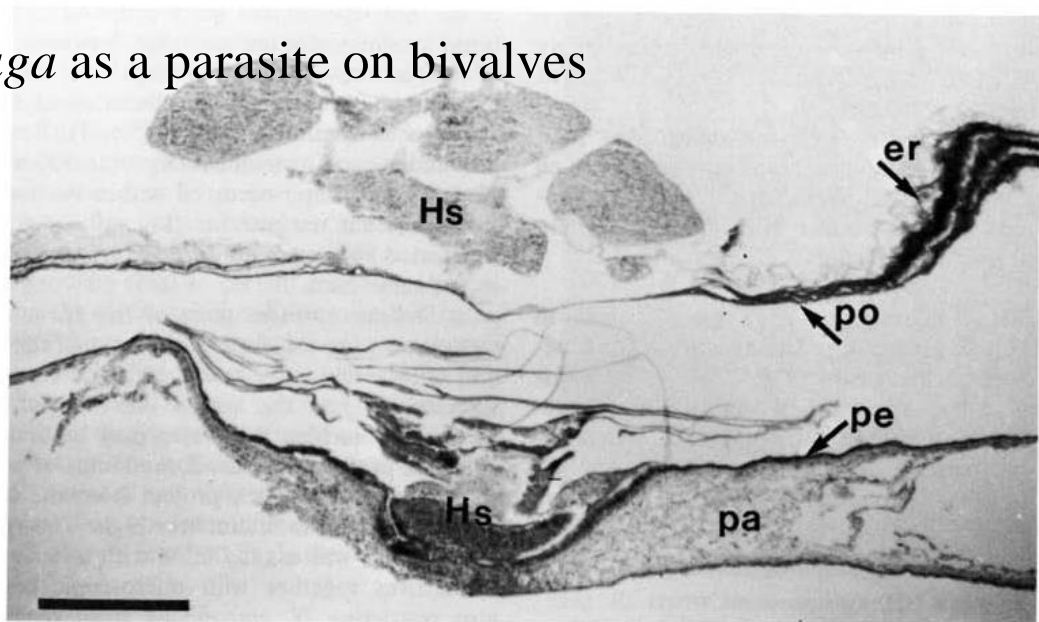


Fig. 9. Section of *Hyrrokkin sarcophaga* specimen (Hs) sitting on *Lima (Acesta) excavata*. The pseudo-podia attack the tissues of the bivalve. pa = pallium, pe = pallial epithelium, po = periostracum, er = excreted residues (Sample No. 32). Scale bar = 1 mm.

Hyrrokkin sarcophaga as a parasite on bivalves



Delectopecten vitreus
North Sea, English Klondike
NMR 38951. Common size 15 mm

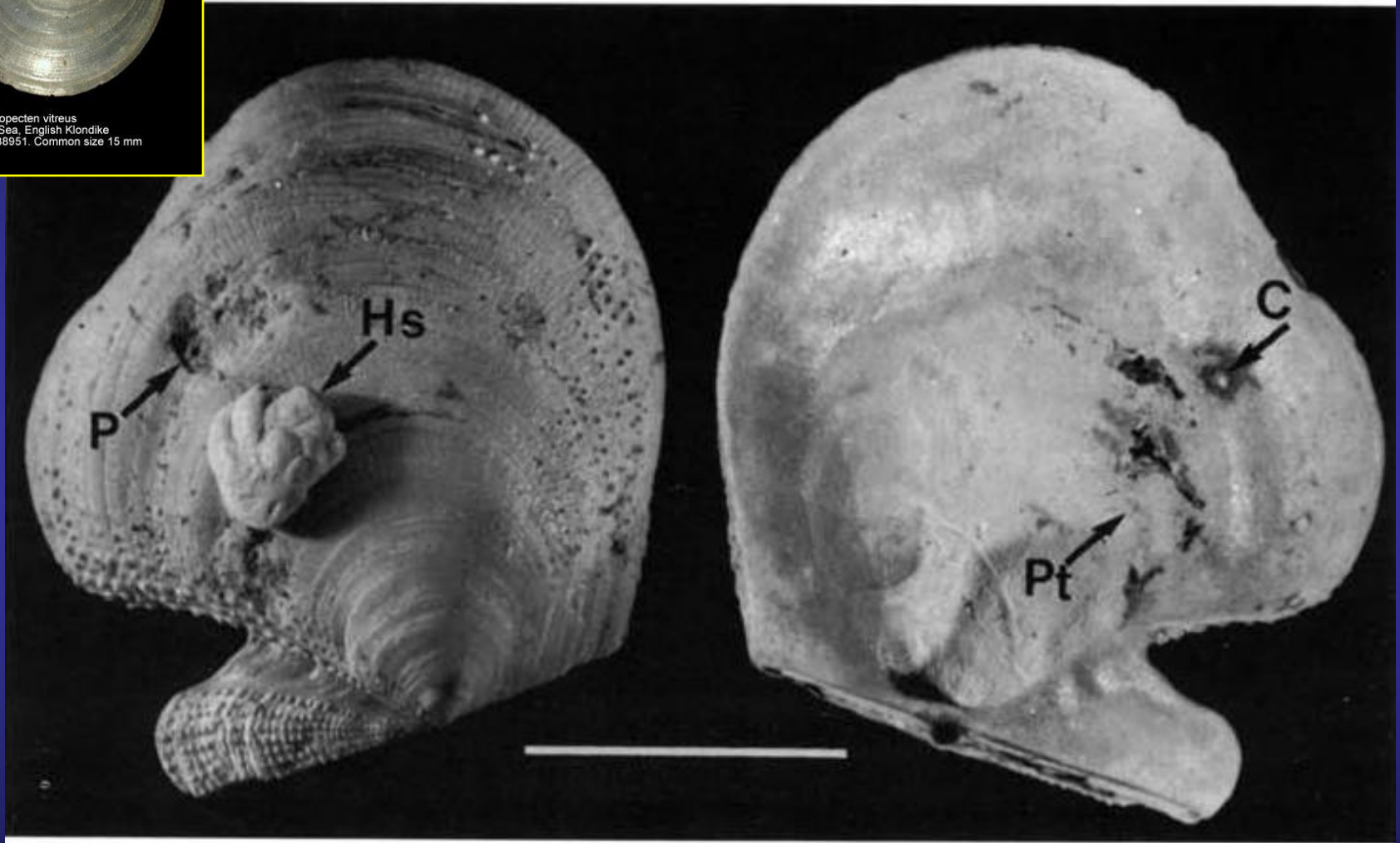
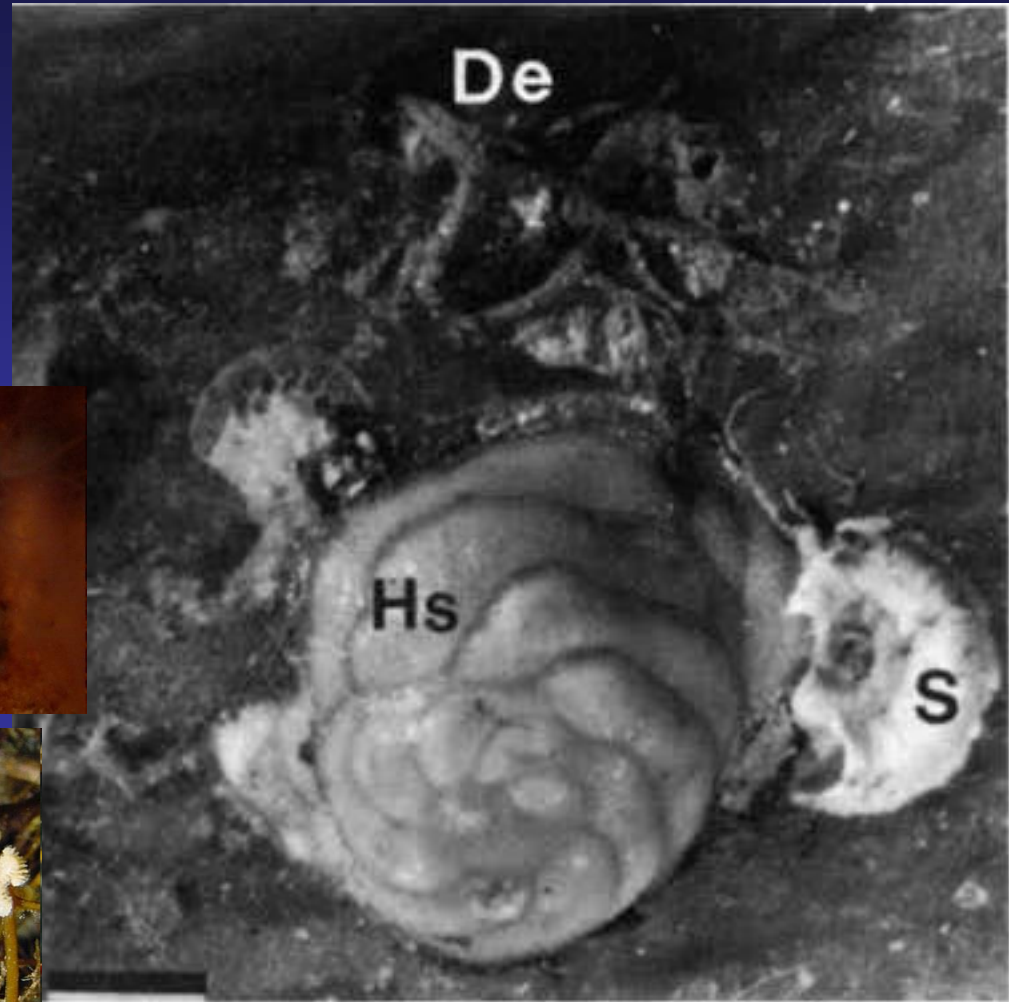


Fig. 11. A living *Hyrrokkin sarcophaga* specimen (Hs) sitting on a dead *Delectopecten vitreus* specimen. c = callus, p = pit, pt = penetration without a callus, (see Sample No. 45). Scale bar = 1 mm.

(Cedhagen, 1994)

Hyrrokkin sarcophaga as a predator



Они питаются полихетами *Placostegus tridentatus*, *Serpula vermicularis*, *Apomatus similis*, *Spirorbis* sp., колониями мшанок *Disporella hispida*, *Idmidronea atlantica*.

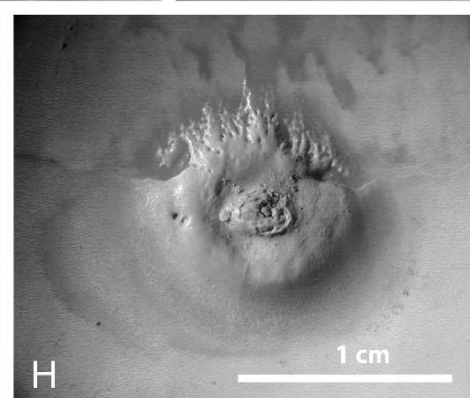
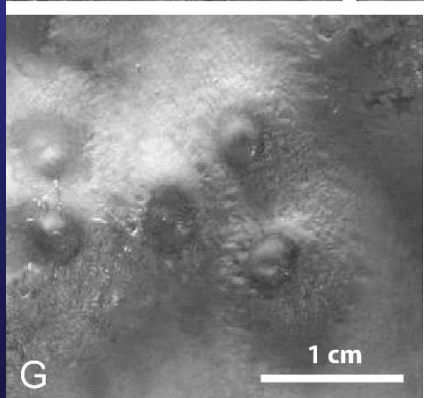
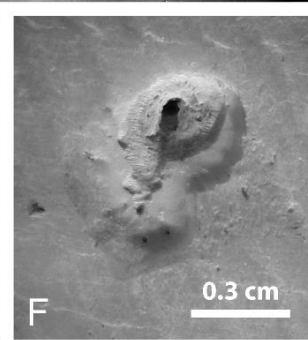
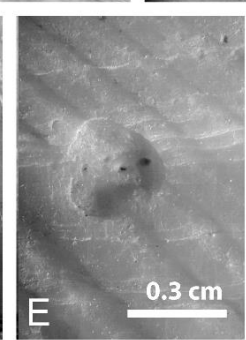
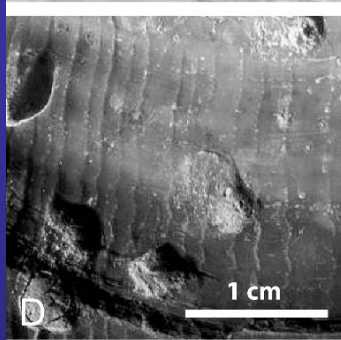
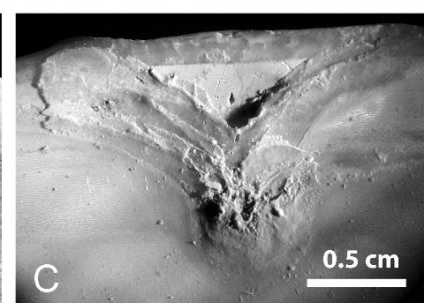
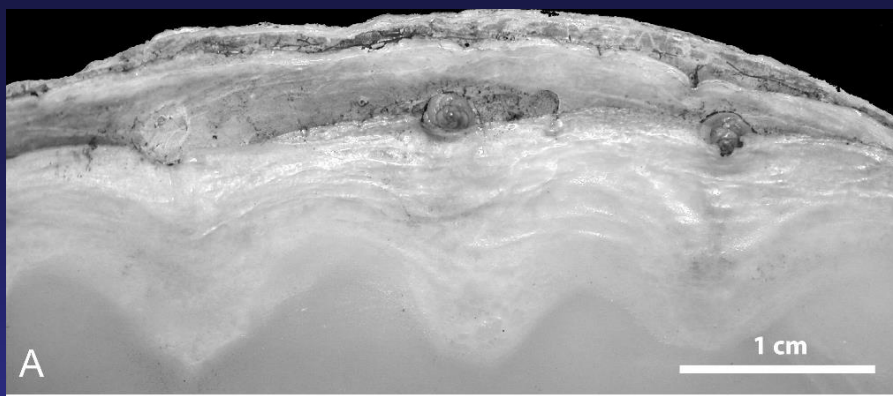
Fig. 13. *Hyrrokkin sarcophaga* parasitizing a *Lima (Acesta) excavata* specimen and simultaneously preying on a *Spirorbis* sp. specimen but not affecting a *Dendrophrya erecta* specimen nearby. (Sample No. 27). Scale bar = 1 mm.

(Cedhagen, 1994)

Hyrrokkin spp. as parasites

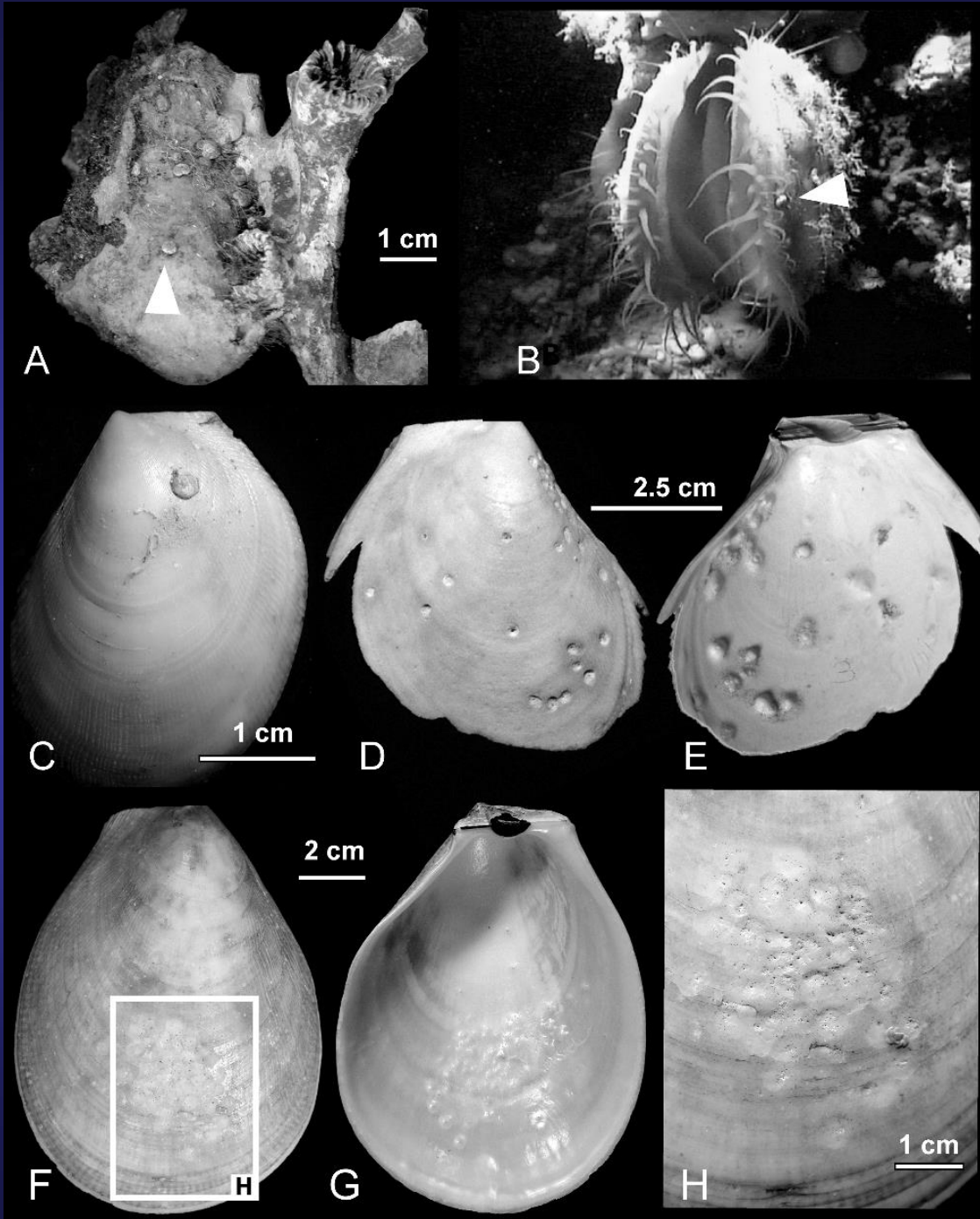
Hyrrokkin spp. and its traces on *Acesta* spp. and the bivalve's callus formation. **A** Three attachments on the inner side of *A. patagonica* (Beagle Channel) with two in situ tests; note the retracted mantle precipitates and the partial embedding of the test to the right. This is the only sample with *Hyrrokkin* being attached to the internal side of *Acesta*. **B** *H. carnivora* close to the margin of *A. excavata* (Mauritania). **C** Irregular callus resulting from a retracted mantle, due to *H. sarcophaga* close to the margin of *A. excavata* (ALK232-BG-1066). **D** *H. sarcophaga* scars on a Late Pleistocene *A. excavata* (COR2-8). **E-F** Varying scar morphology depending on the penetrated mineralogical layers in *A. excavata* (E: calcite, F: calcite and crossed-lamellar aragonite underneath, COR2-39). **G** Inside of D with callus pinnacles. **H** Recent callus in *A. excavata* at the pallial line, note the sealed central canal (ALK232-1066-BG)

(Beuck et al., 2008)



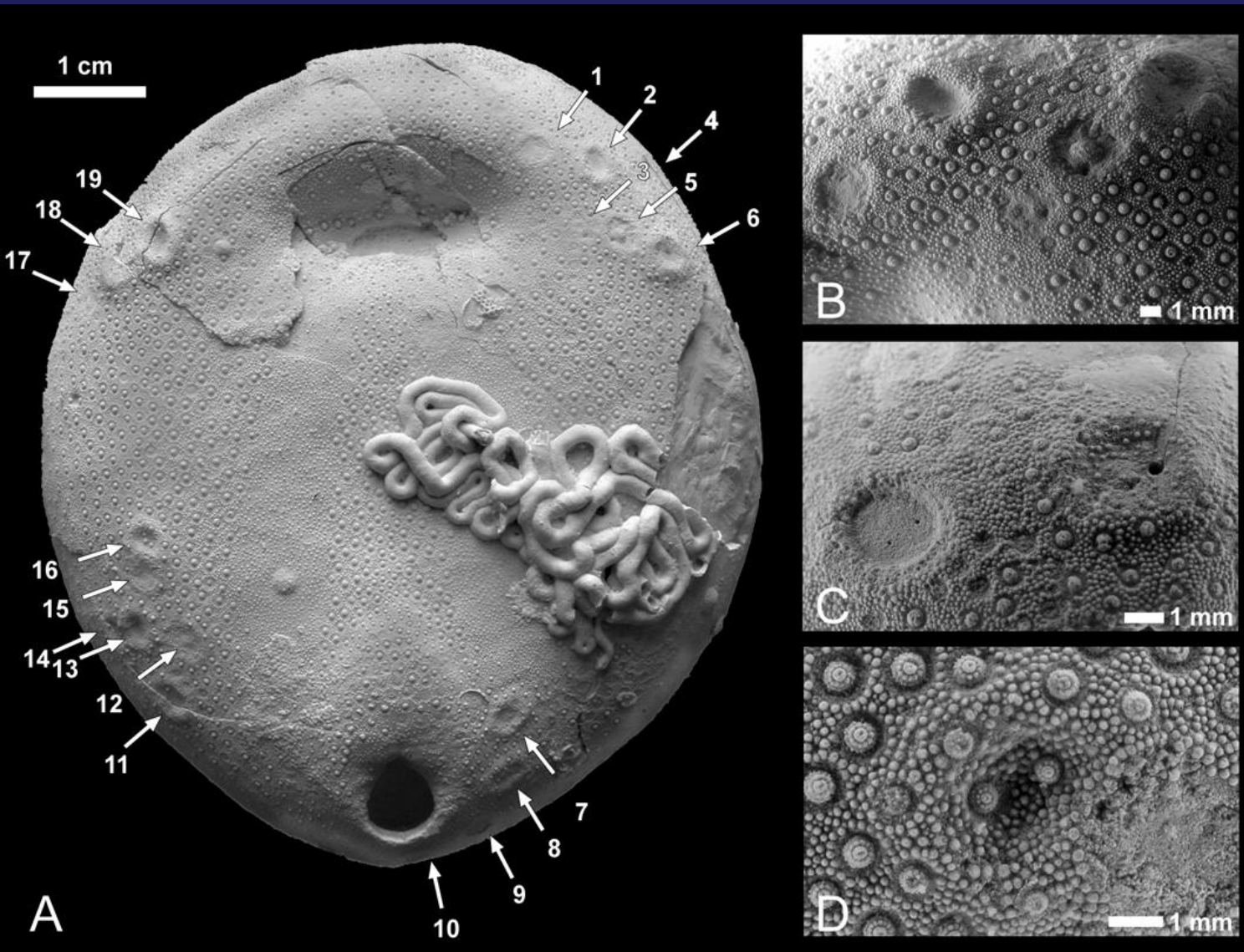
Hyrrokkin spp. as parasites

Overview images of *Hyrrokkin* substrates. **A** Numerous individuals of *Hyrrokkin sarcophaga* (see white arrow) infesting a geodiid sponge, which has overgrown a dead *Lophelia pertusa* branch (LI94-163). **B** Submersible image of a filtering *Acesta excavata* with a large *H. sarcophaga* specimen attached close to the valve margin (Sula Ridge, Norway). **C** Juvenile *A. excavata* with a large *H. sarcophaga* specimen (Pos228-215). **D** Outer surface of a Last Glacial Mediterranean *A. excavata* shell (COR2-39); note the high amount of grooves. **E** Inner side of D showing the protuberances as reaction of the bivalve against infestation (aragonitic callus formation). **F** Recent *A. excavata* (Mauritania) with a multitude of attachment scars produced by *Hyrrokkin carnivora*. **G** Inner side of F, equivalent callus formation as observed for Norwegian *A. excavata* infested by *H. sarcophaga*. **H** Close-up of F showing high attachment scar densities and part of a *H. carnivora* test



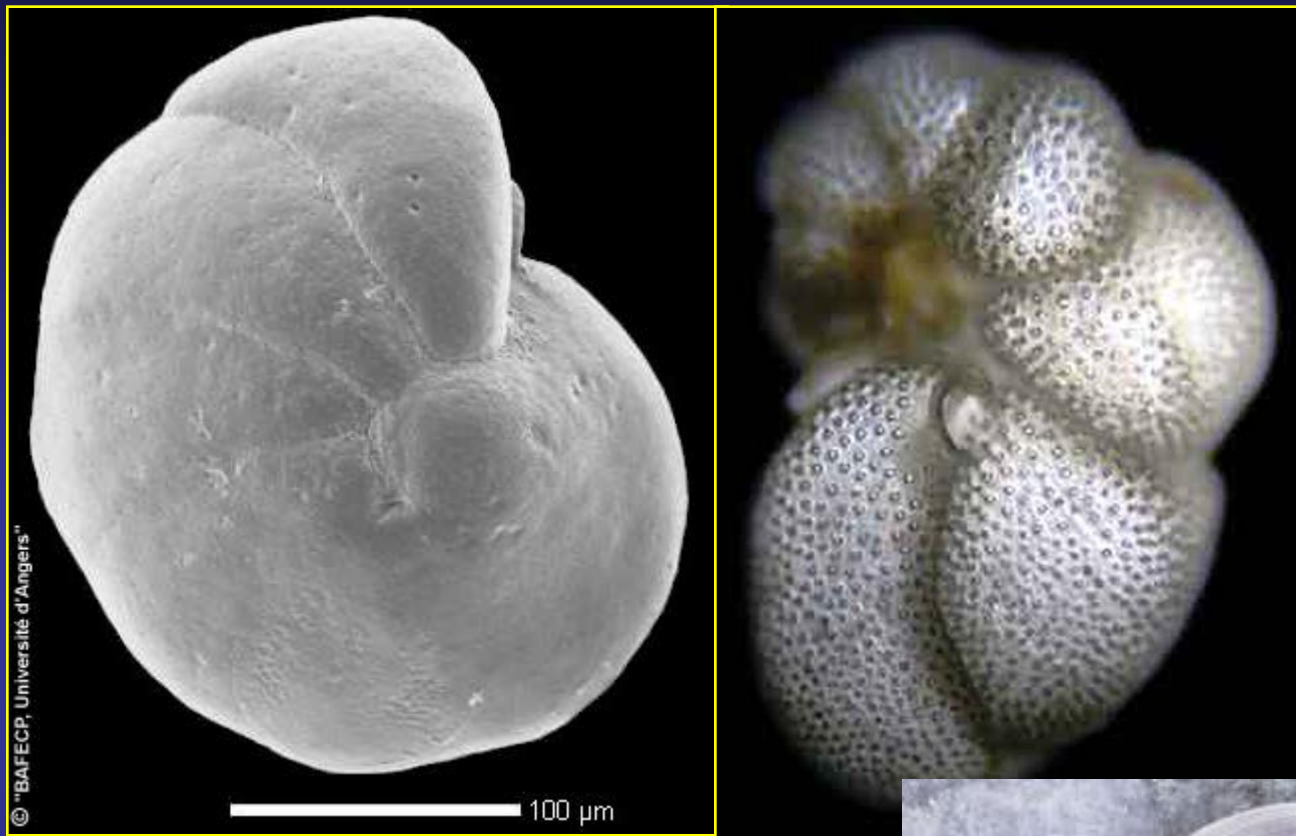
(Beuck et al., 2008)

A Foraminiferal Parasite on the Sea Urchin *Echinocorys*:
 Ichnological Evidence from the Late Cretaceous
 (Lower Maastrichtian, Northern Germany)



A Oral side of *Echinocorys perconicus* (MB.E. 5424) exhibiting 19 circular attachment scars (traces numbered clockwise) B Detail of trace 1 to 6 illustrating the morphological range of the trace with absent (3) to pronounced rim (2), and the absence or presence (5) of a central boss. C Two traces, the left one of which (9) with no, the right one (10) with slight regeneration texture. D Trace with pronounced regeneration pattern (6).

Other foraminifera as parasites



Cibicides refulgens, *Rosalina globularis* осядают на раковину двустворки *Adamussium colbecki*, при этом предпочитают садиться на верхнюю створку (Mullineaux, DeLaca, 1984).

(Alexander, DeLaca, 1987)



Cibicides spp., *Acervulina inhaerens*, *Paromalina coronata* as parasites on bivalves

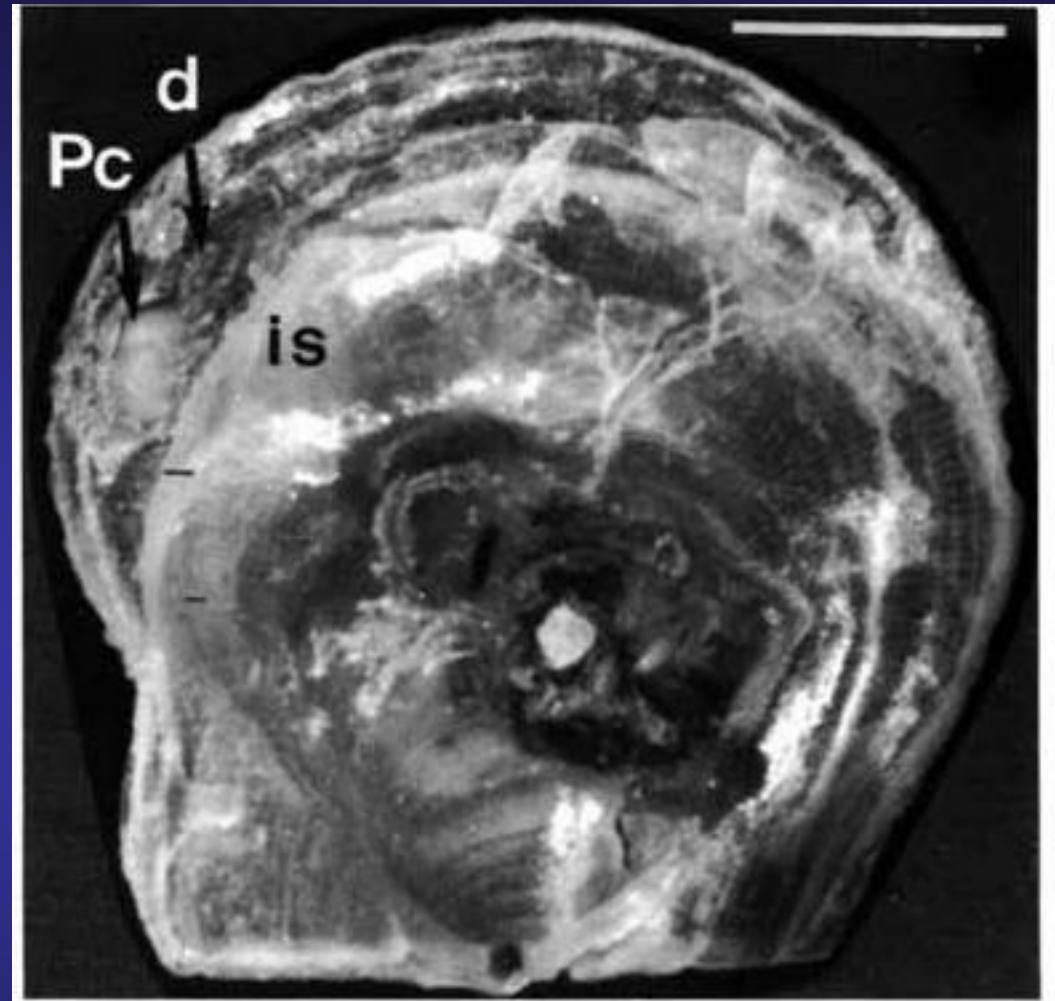
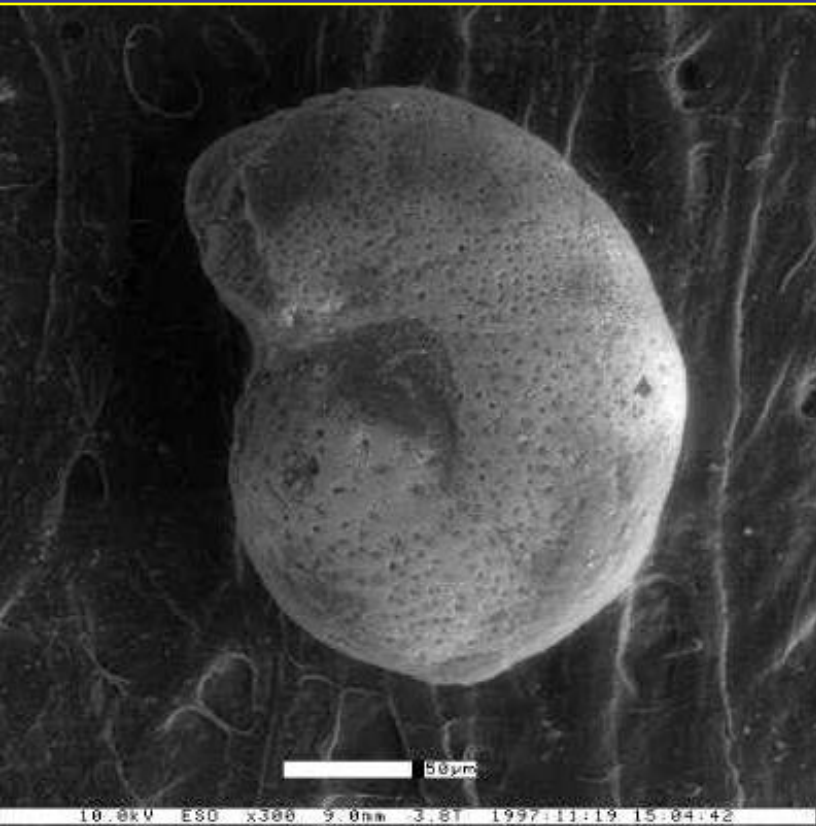


Fig. 12. *Delectopecten vitreus* with a *Paromalina coronata* specimen (Pc) on the inner edge of its shell, causing the bivalve to build an additional, internal shell (ic), d = detritus collected by the foraminiferan (Sample No. 58). Scale bar = 1 mm.

(Cedhagen, 1994)

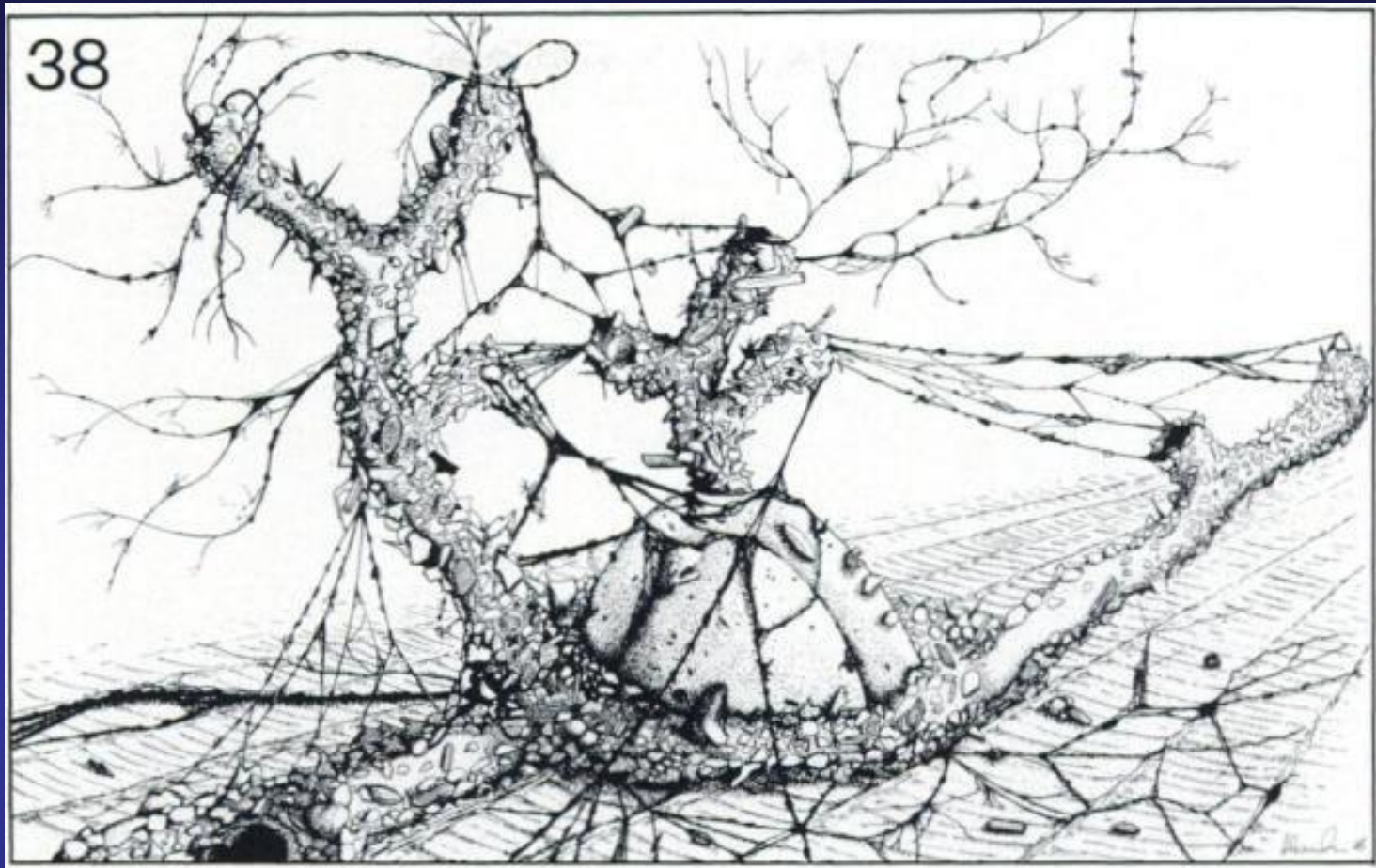


Adamussium colbecki



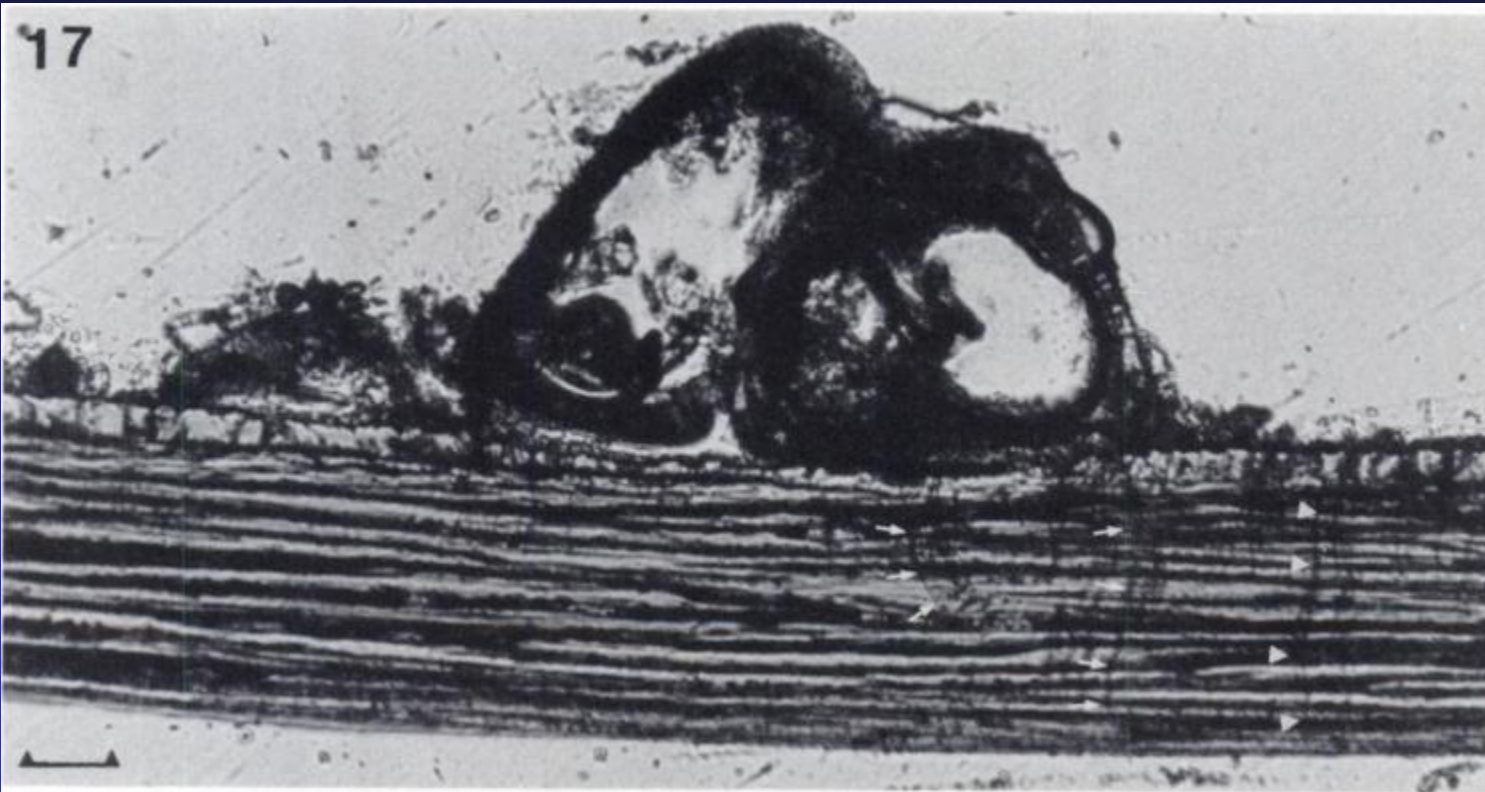
Cibicides refulgens

(Alexander, DeLaca, 1987)



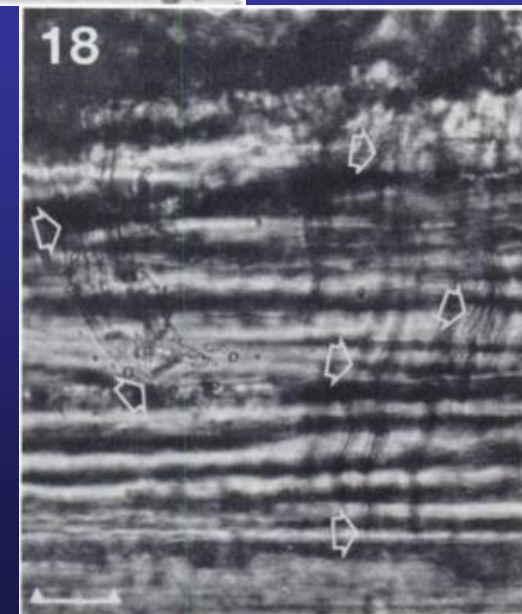
Cibicides refulgens attached to the shell of *Adamussium colbecki*. with pseudopodia deployed from agglutinated structures. (Not to scale.)

(Alexander, DeLaca, 1987)



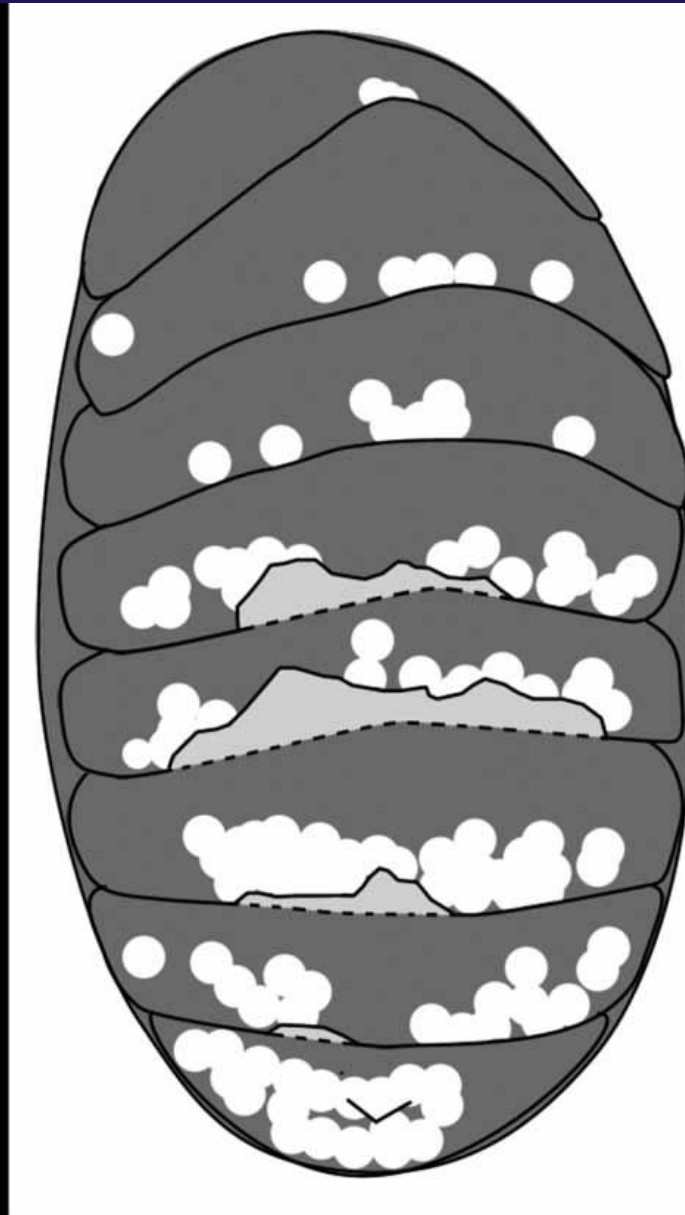
17. Thick cross section through a resin-embedded adult *Cibicides refulgens* attached to *Adamussium colbecki*. Groups of canals are discernible originating from the base of the pit and passing through most of the shell thickness (arrows). Scale bar = 200 mkm.

18. Detail of Figure 17 showing the canals to be continuous through to the inner-most laminae of the scallop shell (arrows). Scale bar = 480 mkm.



(Alexander, DeLaca, 1987)

Foraminifera as parasites of chitons



Photograph and line drawing of *Leptochiton arcticus* specimen heavily infested with epibiotic foraminifera, with anterior at top. White spots on line drawing indicate foraminifera or bioeroded scars caused by foraminifera; light grey areas indicate posterior margins of intermediate valves that have been completely broken away by the bioerosion of epibionts. Scale bar 10 mm.

Hyrrokkin sarcophaga,
Cibicides refulgens,
Cibicides lobatulus,
Cibicides wuellerstorji

(Sigwart, 2009)

Leptochiton arcticus

Invertebrate Biology 118(2): 95–108.

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***Smithsoninema inaequale* n.g. and n.sp. (Nematoda, Leptolaimidae)
inhabiting the test of a foraminiferan**

W. Duane Hope^{1,a} and Alexei V. Tchesunov²

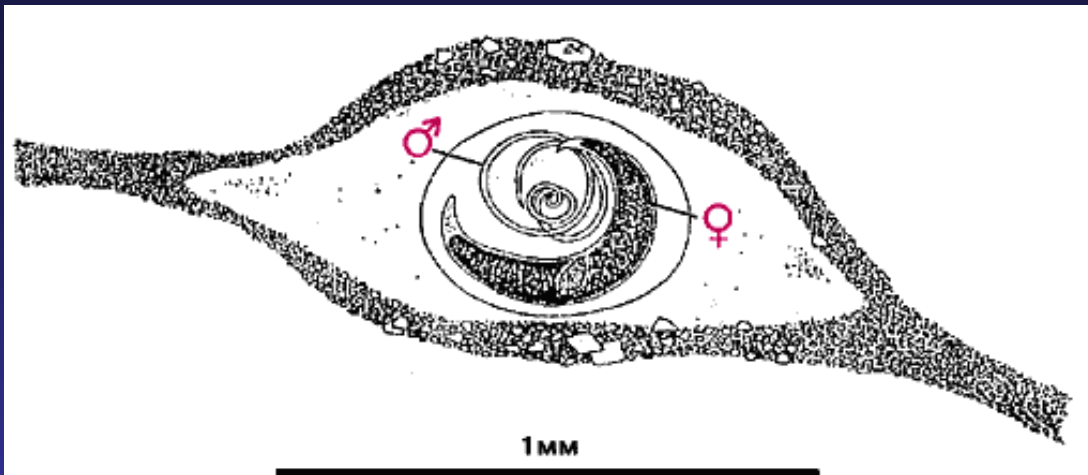
¹ Department of Invertebrate Zoology, National Museum of Natural History, Smithsonian Institution,
Washington, D.C. 20560-0163 USA

² Department of Invertebrate Zoology, Faculty of Biology, Moscow State University, Moscow, 119899, Russia

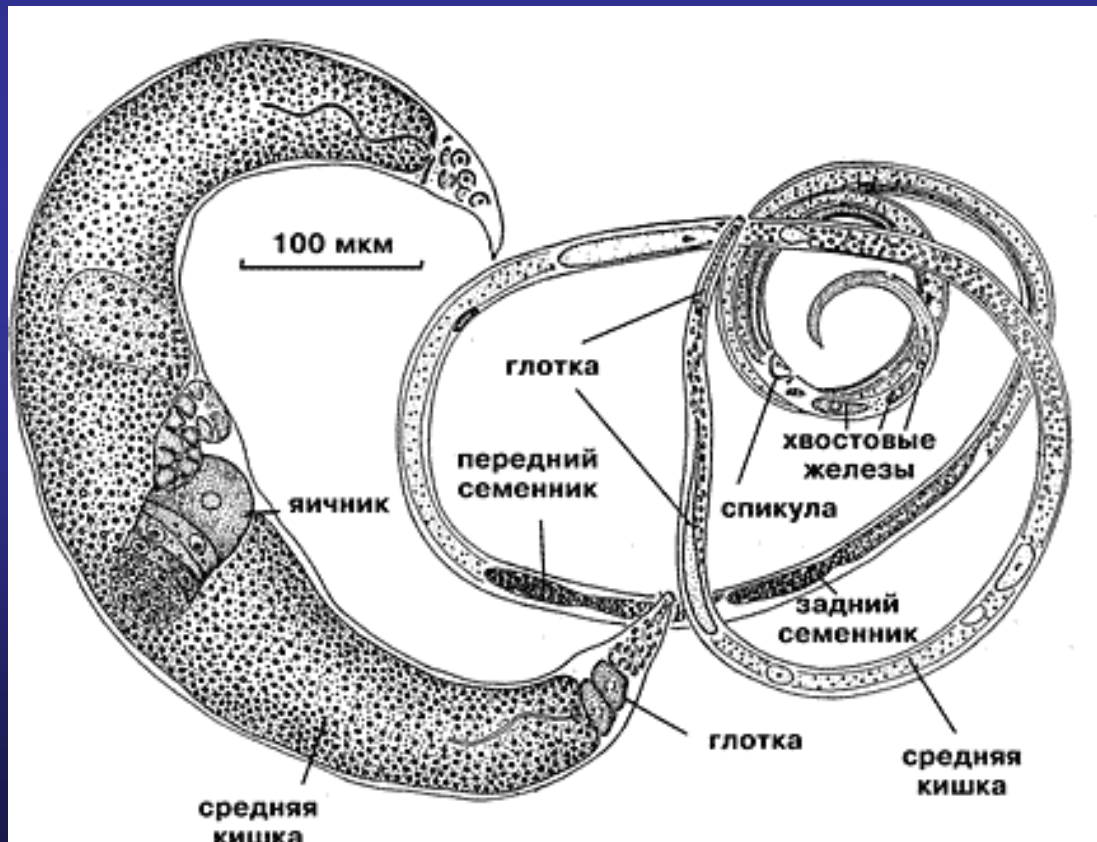
ПРИРОДА

№3, 2000 г.

**Многоклеточные паразиты простейших
А.В.Чесунов, Д.М.Милютин, А.В.Евсеев**

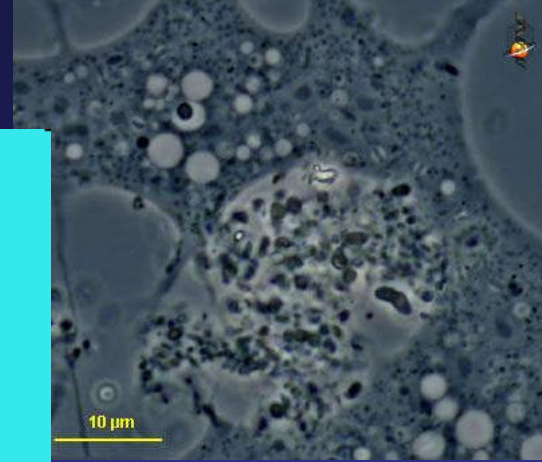
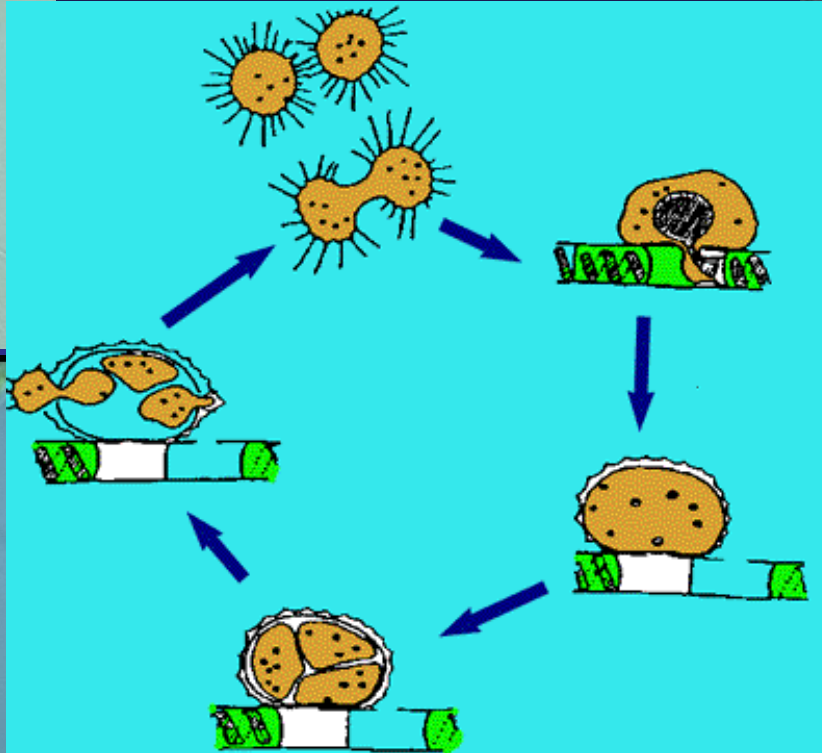
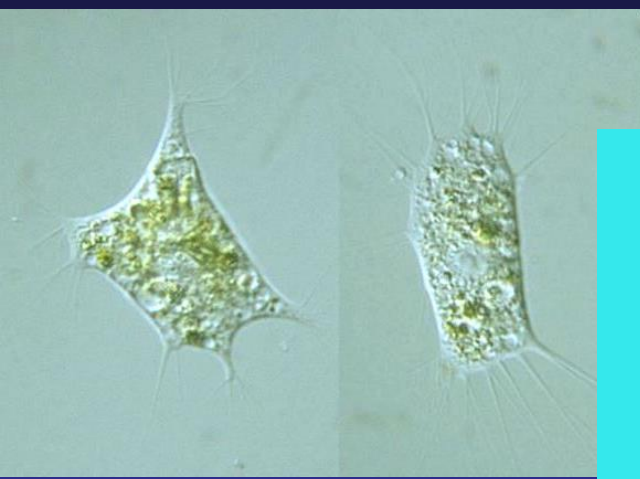


Vanhoeffenella aff. gaussi

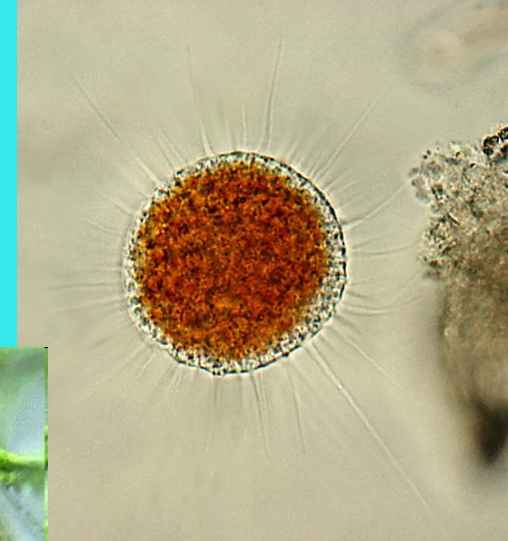


Smithsoninema inaequale

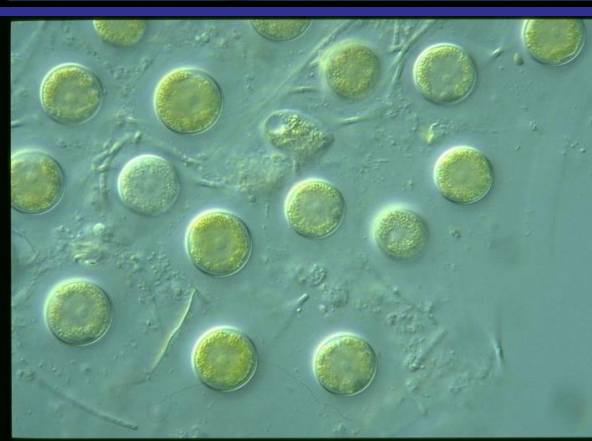
Vampyrellidae Filosea



Arachnula



Vampyrella lateritia



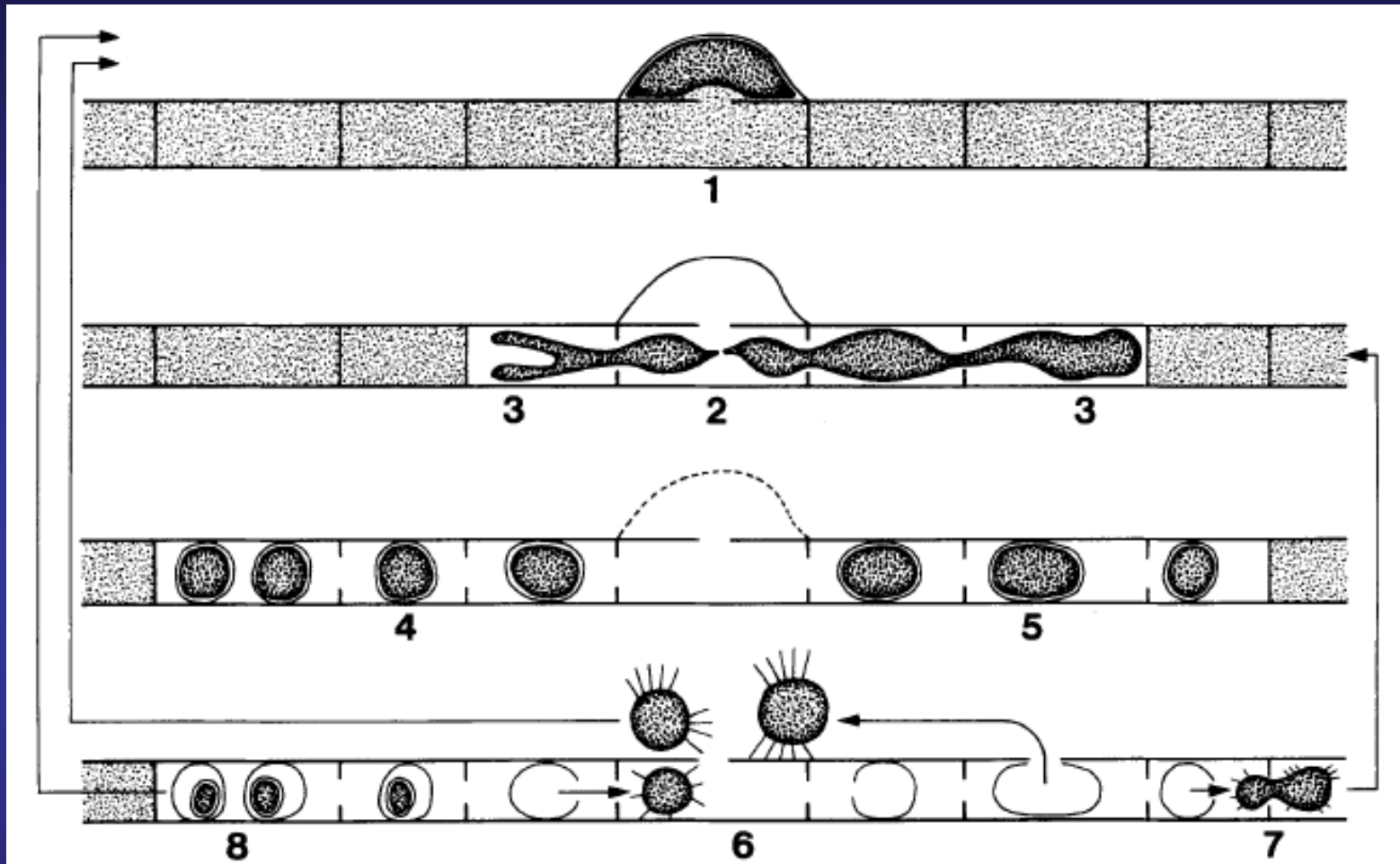
Nuclearia



<http://ameba.i.hosei.ac.jp/BIDP/amoeba/QuickE ate/>

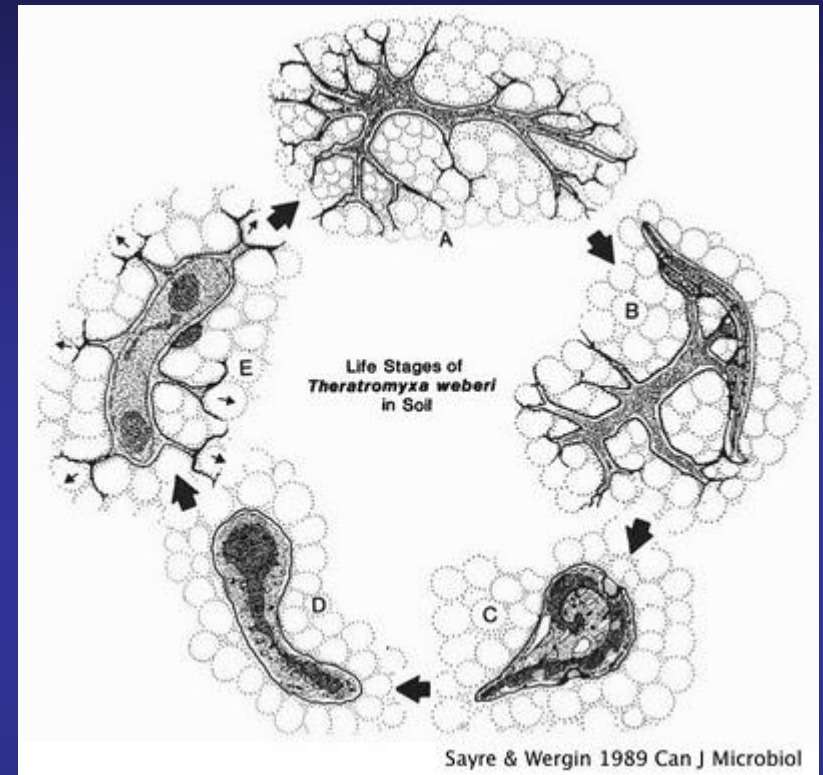
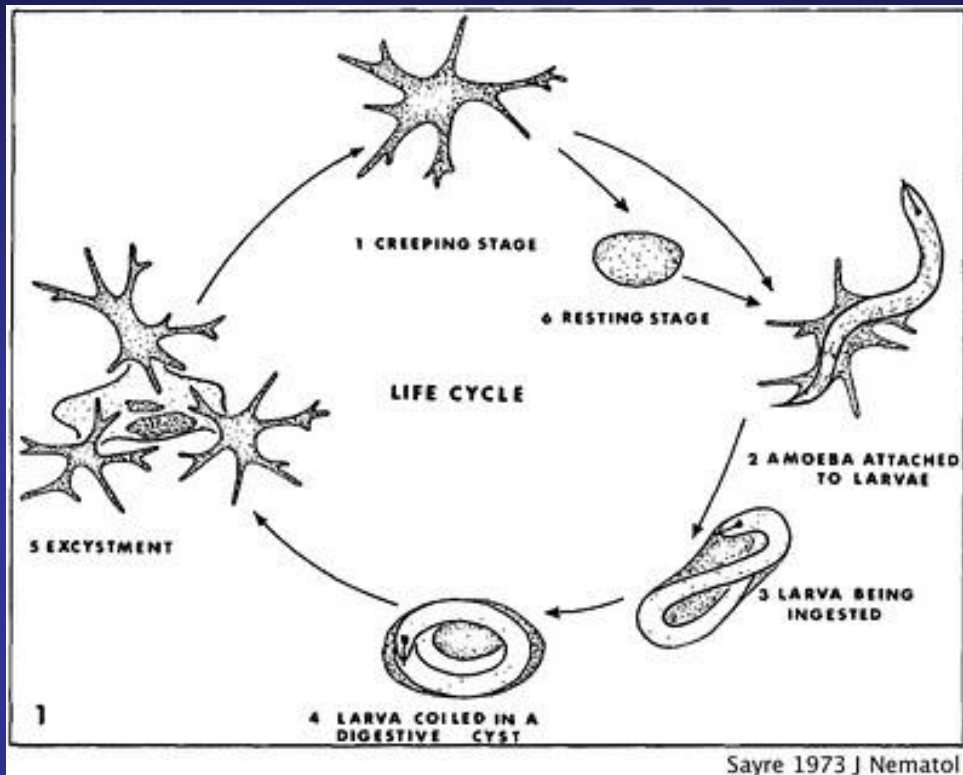
<https://www.arcella.nl/vampyrella>

Vampyrellidae: *Lateromyxa gallica*



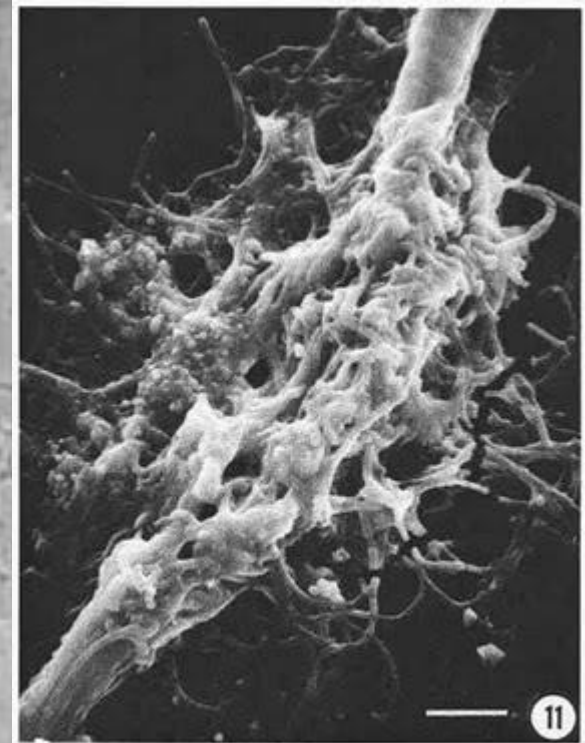
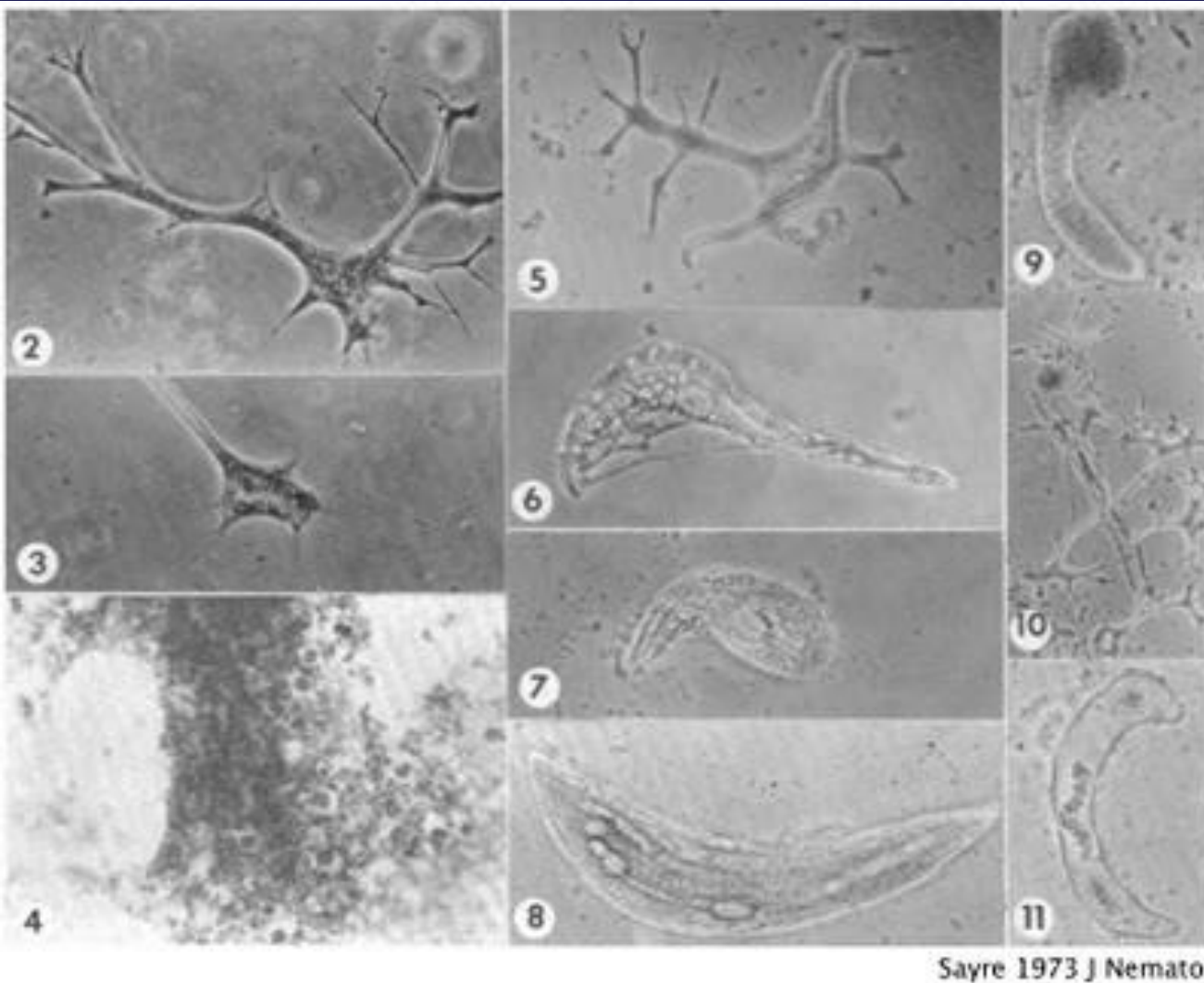
Schematic presentation of the life cycle of *Leptomyxa gallica*. (1) Beginning of a lateral attach against intact *Oedogonium* cells. The attach is preceded by secretion of a cyst-like envelope. After invasion, larger syncytia divide into smaller ones (2) which undergo further divisions during migration (3) through the algal trichome leading to the terminal and obligatory formation of digestive cysts (4) or digestive-multiplicative cysts (5). Excystation is combined with leaving the trichome (6) and starting again at (1) or by attacking the cross walls of adjacent *Oedogonium* cells (7 and 3). Formation of resting cysts (8) sets out from digestive or multiplicative cysts (4, 5) and coincides with the excretion of debris and with the secretion of an additional internal cystic wall (Hulsmann, 2007).

Vampyrellidae *Theratromyxa weberi*



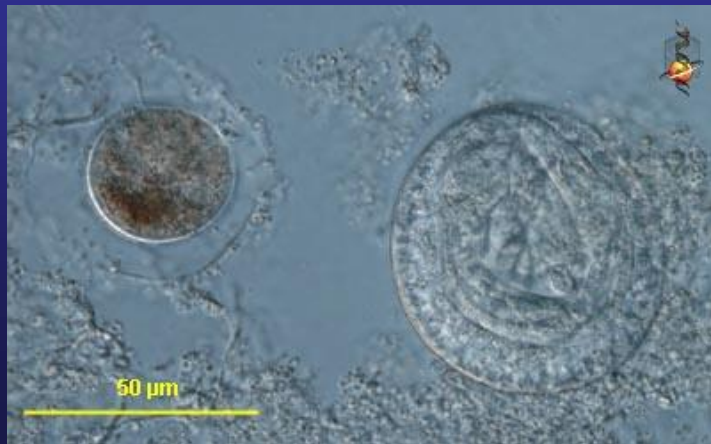
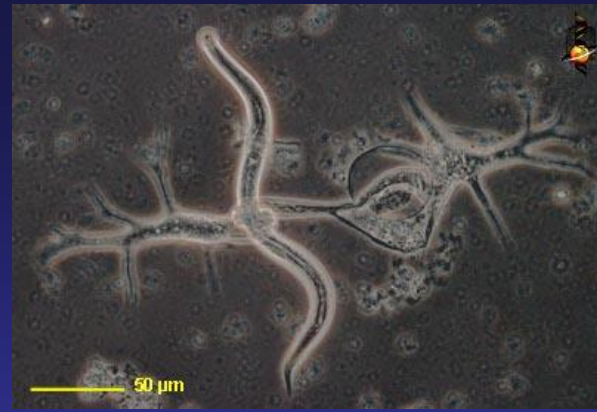
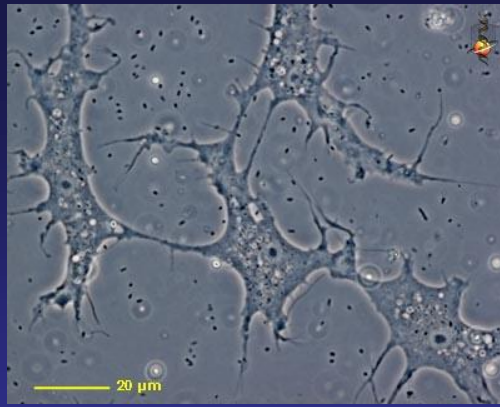
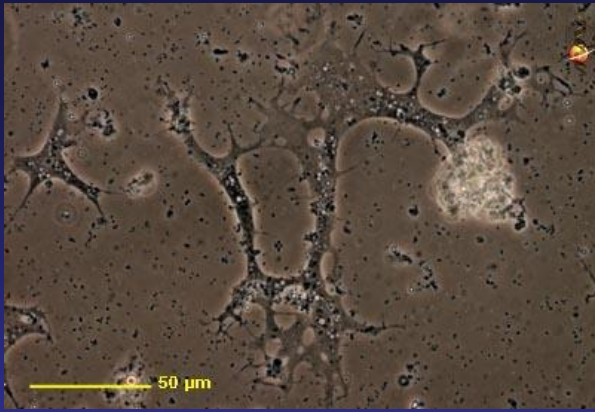
Life cycle of *Theratromyxa*, involving predation on food a little too large for its size followed by long-term digestion and slumber in cysts. Not a bad lifestyle (Sayre, 1973).

Vampyrellidae
Theratromyxa weberi



Sayre & Wergin 1989 Can J Microbiol

Theratromyxa: capturing a nematode. Image 6 shows quite nicely how *Theratromyxa* captures the nematode. This looks rather similar in principle to the feeding veil of dinoflagellate *Protoperidium*. Sometimes the amoeba can capture several nematodes at once. SEM shows amoeba enveloping a nematode (Sayer, 1973; Sayer, Wergin, 1989).



Theratromyxa weberi